S
627.83
N7WCDM
2005

WILLOW CREEK DAM

MANUAL FOR OPERATION AND MAINTENANCE

ATE DOCUMENTS COLLECTION

OCT 15 2005

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
1424 9th Avenue
P. O. Box 201601
Helena, MT 59620-1601

Initial Publication March 1995
Revised September 2005

Montana State Library
3 0864 1003 5141 3

WILLOW CREEK DAM

MANUAL FOR OPERATION AND MAINTENANCE

State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
1424 9th Avenue
P. O. Box 201601
Helena, MT 59620-1601

Initial Publication March 1995
Revised September 2005

Digitized by the Internet Archive
in 2015

https://archive.org/details/willowcreekdamma2005mont

TABLE OF CONTENTS

	Page
PROJECT DESCRIPTION	1
Overview	1
Embankment	1
Outlet Works	2
Spillway	2
Drains	3
Reservoir Location Map (Figure 1)	4
Project Area Map (Figure 2)	5
Dam General Layout Map (Figure 3)	6
STATISTICAL INFORMATION	7
OPERATING PROCEDURES	11
Dam Operator	11
Method and Schedule of Operation	12
Safe Drawdown	13
Gate Operation	13
Spillway	14
Storage Determination	14
Weather Monitoring	15
Interaction with Other Dams	16
Emergency	16
INSPECTION AND MONITORING	17
Structural Features Inspection	17
Riprap Inspection	18
Instrumentation	18
Seepage	18
Seepage Monitoring	19
MAINTENANCE	21
Routine Maintenance	21
Annual Maintenance	22
Record Keeping	22
REFERENCES	25

TABLE OF CONTENTS (continued)

	Page
APPENDICES	27
A. RATING CURVES AND TABLES	A1
Table 1. EAST SHORE SLOPE-STORAGE-ELEVATION TABLE	A2
Table 2. BOAT RAMP SLOPE-STORAGE-ELEVATION TABLE	A5
Table 3. TOTAL STORAGE TABLE	A9
Table 4.. SPILLWAY RATING CURVE AND TABLE	A11
B. INSPECTION REPORT FORM	B1
C. O&M MANUAL DISTRIBUTION LIST	C1
D. MONITORING WELL LOGS	D1
E. PROJECT DRAWINGS	E1

PROJECT DESCRIPTION

OVERVIEW

Willow Creek Reservoir is owned by the Montana Department of Natural Resources and Conservation (DNRC) and is managed by the State Water Projects Bureau (SWPB) of the DNRC. The Willow Creek Water Users Association (herein called the "association") operates and maintains the dam.

This on-stream reservoir is located in Madison County, 3 stream miles southwest of the line separating Madison and Gallatin Counties. The project is approximately 10 miles upstream of the town of Willow Creek, 4 miles east of the town of Harrison, and 17 miles upstream of the city of Three Forks. The reservoir is fed by Willow Creek from the west, Dry Hollow Creek from the southwest, and Norwegian Creek from the south (see Figures 1 and 2). Figure 3 provides a general layout of the dam, spillway and outlet works.

Water from the reservoir is used for irrigation water supply. The reservoir is also used for water-based recreation.

EMBANKMENT

The earthfill dam was constructed in 1938. The dam is founded on Precambrian metamorphic bedrock. The curved-axis dam is 105 feet high and 453 feet long, and has a crest width of 28 feet. The upper 10 feet of the upstream slope is 1v on 2h; below, it changes to 1v on 3h. The downstream slope is 1v on 1.5 h. Embankment materials were obtained from spillway, tunnel, and cutoff excavations, as well as onsite quarries and borrow pits.

OUTLET WORKS

The dam's outlet works is located in the left abutment. The outlet works consists of an inlet structure, reinforced concrete tunnel, control tower with gatehouse, and an outlet structure.

The reinforced concrete tunnel is a 60-inch diameter straight-legged horseshoe section, approximately 362 feet long, of which 154 feet is cut and cover beneath the embankment and 208 feet is lined tunnel. The conduit ends at the tunnel downstream portal. A concrete chute, with semicircular side slopes extends approximately 20 feet downstream of the portal.

The 8-foot diameter dry gate tower is located about 230 feet downstream of the intake structure, near the dam centerline. The control for the 54-inch diameter butterfly operating valve is at the top of the tower, while the control for the 54-inch diameter emergency gate valve is located at the bottom of the tower. A jet pump is used to dewater the tower. The gate tower is covered by a locked gatehouse.

SPILLWAY

The spillway is located in rock at the left abutment. The spillway was originally rock-lined, but it was reconstructed with a concrete liner in 1945. The unlined approach channel to the uncontrolled concrete ogee crest is short and unobstructed. There is no log boom upstream of the spillway. The crest discharges to a concrete chute that ends with a flip bucket near the creek level.

The spillway is 90 feet wide at the crest and tapers to 50 feet wide at the toe with a maximum capacity of 8,300 cubic feet per second (cfs).

DRIANS

There are no known internal drains at the dam.

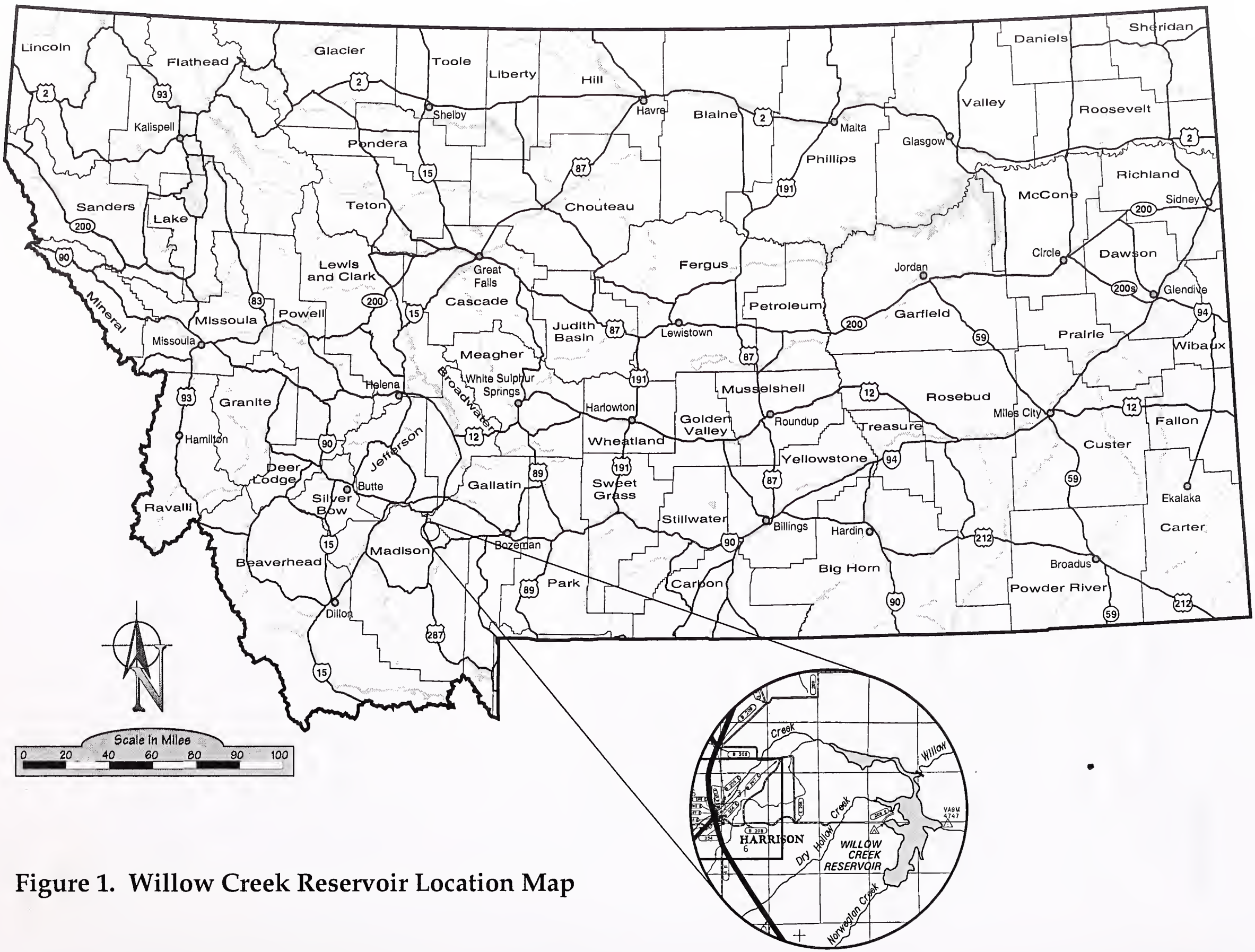


Figure 1. Willow Creek Reservoir Location Map

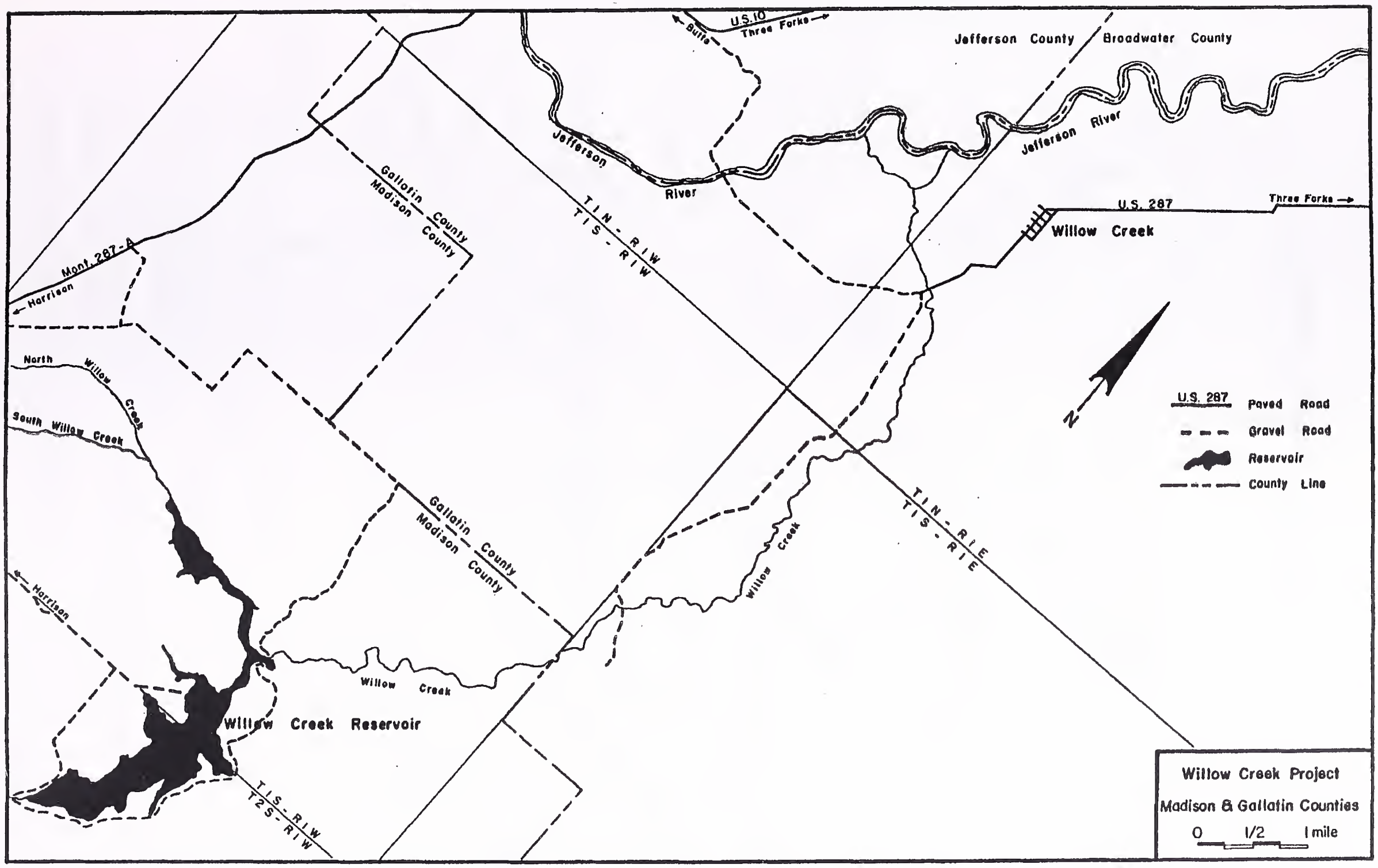


Figure 2. Willow Creek Dam Project Map

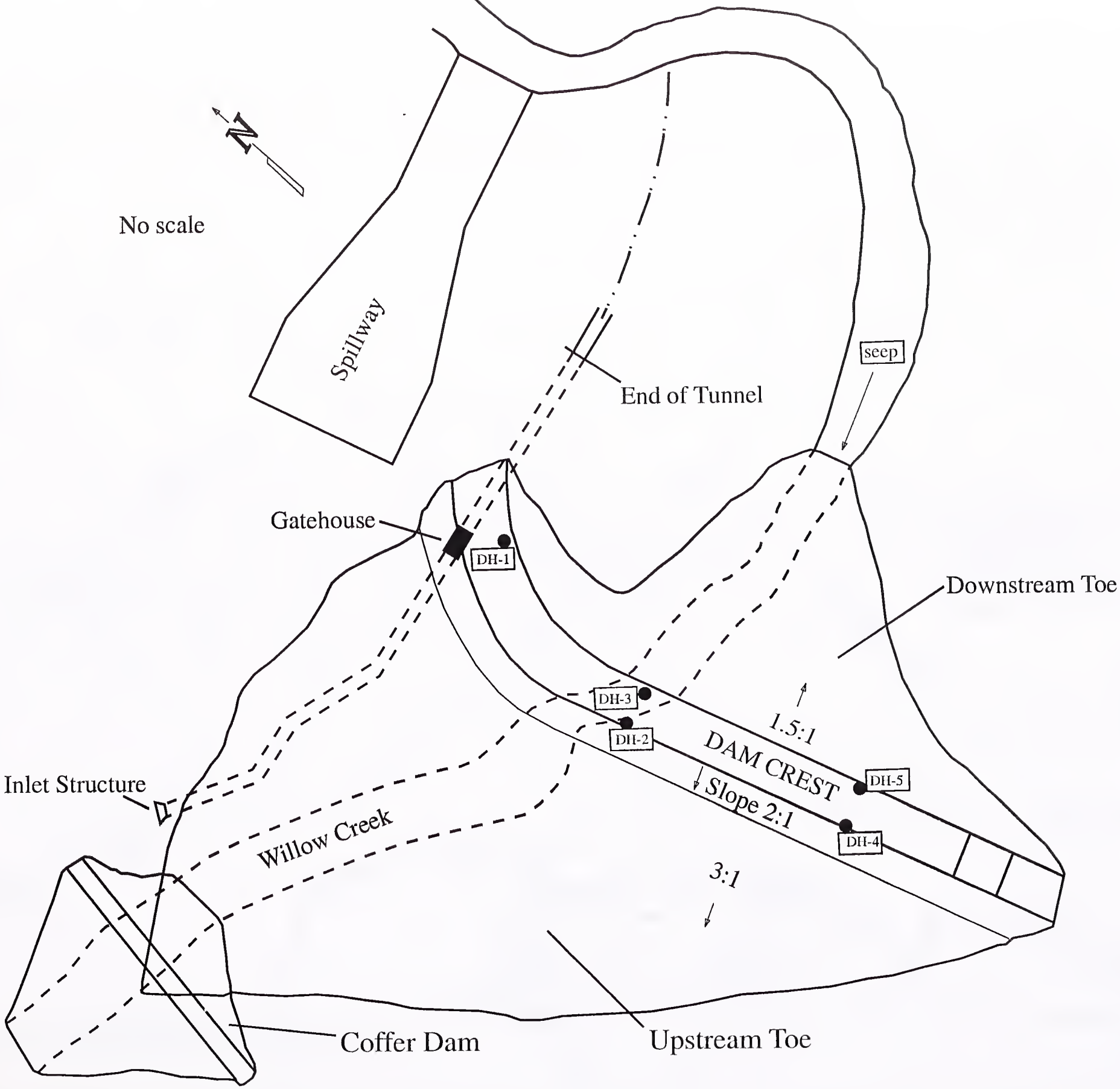


Figure 3. Willow Creek Dam General Layout

STATISTICAL INFORMATION

1. General

a. Owner	Montana Department of Natural Resources and Conservation (DNRC)
b. Operator	Willow Creek Water Users Association
c. Location	Section 35, Township 1 South, Range 1 West, MPM (dam location)
d. Latitude Longitude	45.71° 111.70°
e. County--State,	Madison--Montana
f. Watershed Location,	Willow Creek, Jefferson River Basin
g. Drainage Area,	155 square miles

2. Principal Elevations (feet above mean sea level)

a. Minimum Dam Crest	4,744.5 feet
b. Normal Full Pool	4,736.0 feet
c. Spillway Crest	4,736.0 feet
d. Outlet Design Invert	4,666.5 feet
e. Toe of Dam	4,639.5 feet

3. Reservoir

a. Length of Maximum Pool (north and south--approximate)	2.0 miles
b. Length of Maximum Pool (east and west--approximate)	1.6 miles
c. Maximum Reservoir Level of Record (June 30, 1963)	4, 736.7 feet (19,230 acre-feet)
d. Surface Area at Normal Pool	885 acres

4. Storage

a.	Maximum Storage (pool at dam crest)	26,600.acre-feet
b.	Active Storage (pool at spillway crest)	18,000 acre-feet
c.	Maximum Surcharge (from spillway crest to dam crest)	8,600 acre-feet

5. Hydrology

a.	Probable Maximum Flood (PMF) (March, 1993)	61,300 cfs (170,090 acre-feet)
b.	500-Year Return Period Flood	4,618 cfs
c.	100-Year Return Period Flood	2,936 cfs
d.	Maximum Inflow of Record (1938-1992) at USGS gage 06035000 (2.2 miles upstream from the dam on Willow Creek	813 cfs

6. Embankment (Dam)

a.	Type	Earthfill
b.	Hydraulic Height	105 feet
c.	Crest Length	453 feet
d.	Crest Width	28 feet
e.	Downstream Slope	1v on 1.5h
f.	Upstream Slope	1v on 3.0h

7. Outlet Works

a.	Size	60-inch, straight legged horseshoe-shaped, reinforced concrete and cast iron
b.	Length	362 feet
c.	Control	54-inch diameter gate valve upstream (emergency gate)

	and a 54-inch butterfly valve (operating gate)--gate valve is operated from the bottom of a 96-inch diameter tower, while the butterfly valve is operated from the top of the tower
d. Discharge Capacity (pool at dam crest)	700 cfs
e. Trashrack	Yes

8. Spillway

a. Location	Left abutment
b. Type	Uncontrolled ogee
c. Width	90 feet tapering to 50 feet
d. Length	240 feet
e. Capacity (pool at dam crest)	8,300 cfs

OPERATING PROCEDURES

The Willow Creek Water User's Association operates Willow Creek Dam and Reservoir to insure safe operation of the project and to provide an adequate supply of irrigation water to meet contracts with water users without exceeding safe storage or flow levels.

DAM OPERATOR

The responsibility for the daily operation of the dam and reservoir rests with the association and its dam operator. The dam operator is generally authorized to operate the reservoir to meet the association's goal of providing an adequate supply of irrigation water to meet water user's contracts without exceeding safe storage and flow levels. The dam operator's specific responsibilities are to:

1. Operate the mechanical features of the outlet works. The outlet gates are normally operated manually with a hand crank.
2. Coordinate filling of the reservoir and the release of water.
3. Notify the SWPB of any unusual occurrences such as vandalism, impending floods, structure failure, or excessive seepage.
4. Perform various maintenance tasks.
5. Monitor weather conditions.
6. Monitor seepage.

Typically, the out-going dam operator, the association and the SWPB train a new dam operator. The dam operator's training focuses on operating the mechanical gates, measuring the storage levels, measuring the rate of water release, observing the dam and the area for any unusual conditions, and record keeping.

The dam operator normally is available to observe the dam and perform operating functions daily during the times of rapid reservoir filling. During the remainder of the filling and irrigation seasons, the operator is at the dam three to five times per week. At other, times the operator visits the dam weekly or monthly. The dam operator normally does not visit the dam during the winter months due to poor access because of snow.

Communication among the dam operator, the association, and the SWPB usually takes place by telephone. Although no routinely available, radio communication way be established during emergencies or unusual occurrences, radio communication may be established so that the dam operator can speak directly with county authorities and communicate indirectly with the SWPB staff (see *Willow Creek Dam Emergency Plan*).

METHOD AND SCHEDULE OF OPERATION

The association's goal is to have the reservoir full before contract holders start putting in calls for water. Except during very dry years, the reservoir fills, and some water flows over the spillway. The date the irrigation releases begin varies from year to year, with late April typically being the earliest. Irrigation releases usually end by October 1, as specified in the water purchase contracts. The actual dates that releases begin and end depend on a year's climatological and hydrological conditions.

Maximum Winter Storage: The maximum reservoir elevation for winter storage is 4,726.0 feet with 10,924 acre-feet of storage. This winter maximum helps prevent damage to the riprap and embankment from wind-driven waves and ice.

Minimum Winter Storage: The minimum reservoir elevation for winter storage is 4,676.0 feet with 498 acre-feet of storage.

This winter minimum helps prevent ice damage to the inlet structure for the outlet works.

Minimum Outlet Discharge: Fish, Wildlife and Parks (FW&P) recommends a minimum flow of 14 cfs be maintained at the dam outlet. FW&P cautions that stoppage of dam releases in winter is a serious problem to downstream fishery.

SAFE DRAWDOWN

Because the stability of Willow Creek Dam has not been thoroughly investigated, SWPB recommends that drawdown rates not exceed one foot per day.

GATE OPERATION

With the reservoir pool at the dam crest, the outlet works capacity is 700 cfs.

The outlet gates are normally operated with a hand crank. The outlet works are intended for controlling the release of irrigation water and not for providing emergency relief. The gates are also used to draw down the water level in the fall if the SWPB determines that the level is too high for safe winter and runoff season operation. Outlet releases during the non-irrigation season are usually dictated by river flows and freeze/thaw conditions.

The maximum gate opening for the operating gate is 27 inches. The maximum gate opening for the emergency gate is 54 inches. Openings in excess of these amounts may damage the gate, gate frame, gate stem or the gate operating pedestal. These openings are measured on the exposed portion of the gate stem between the top of the pedestal and the bottom of the stop nut (or top of the gate stem if there is no stop nut).

SPILLWAY

With the reservoir pool at the dam crest, the spillway capacity is 8,300 cfs. A spillway rating table is shown in Appendix A.

When the discharge of the spillway is at or near 8,300 cfs, the sidewalls of the chute may be overtopped. The extent of such overtopping and the resulting damage to the spillway are unknown.

STORAGE DETERMINATION

The reservoir volume and water surface elevation is determined by taking a slope measurement. The slope pins (rebar) are located approximately 100 yards upstream of the dam on the east side of the reservoir along the road which slopes down to the reservoir. The 0+00 pin is about 25 feet south of a one room cabin. Measure from the 0+00 pin to the water surface. The elevation of the reservoir surface and the storage can then be found using the East Shore Slope-Elevation-Storage-Table (Table 1) in Appendix A.

The reservoir volume and water surface elevation can also be determined by taking a slope measurement at the boat ramp on the west side of the reservoir. Slope pins have not been installed. The initial point (0+00) begins at the first horizontal joint below the top of the boat ramp. Measure from the 0+00 point to the water surface. The elevation of the reservoir surface and the storage can then be found using the Boat Ramp Slope-Elevation-Storage-Table (Table 2) in Appendix A.

Reservoir volume and water surface elevation can also be determined using a level off the spillway crest and measuring down to the water surface. The vertical distance is subtracted from the

spillway crest elevation to determine the water surface elevation. Volume of the reservoir is then determined from the Total Storage Table (Table 3) in Appendix A.

WEATHER MONITORING

The dam operator monitors weather conditions through local weather forecasts and the National Weather Service (NWS).

If severe flooding is anticipated, the NWS Great Falls Office (406-453-2081 or 406-453-4561) should be contacted for information about the storm, such as the estimated storm intensity and duration, runoff duration (above base flow), and total flood volume of the storm in the Willow Creek drainage.

INTERACTION WITH OTHER DAMS

Except for irrigation diversion dams, Toston Dam and Canyon Ferry Dam are the next dams downstream from Willow Creek Dam. The safety of these dams is not affected by the normal operation of Willow Creek Dam.

The two largest dams located upstream of Willow Creek Dam are Cataract Creek Dam (maximum storage 1,800 acre-feet and maximum outlet/spillway capacity 1,410 cfs) and Norwegian Creek Dam (maximum capacity 1,910 acre-feet and maximum outlet/spillway capacity 1,200 cfs). Because of the surcharge of Willow Creek Reservoir, the normal or emergency operation of these dams is not a safety concern to the Willow Creek Dam.

Therefore, interaction with other dams is not a concern during normal operations.

EMERGENY

If it appears that Willow Creek Dam will breach, or during other emergency operations, the dam operator will initiate the **Willow Creek Dam Emergency Plan** and notify the operators at Toston Dam (**1-406-266-3869**) so that they can initiate their Emergency Plan.

INSPECTION AND MONITORING

The SWPB inspects the dam annually. Appendix B includes an example of a SWPB inspection report form. In addition to annual inspections, SWPB personnel will inspect the dam and reservoir during and after heavy runoff and severe rainstorms and windstorms, during high storage periods, and after an earthquake. The embankment is not monitored by instrumentation.

STRUCTURAL FEATURES INSPECTION

Structural features include the embankment, gatehouse, outlet works, and spillway. The SWPB will inspect these structures annually as part of its inspection program. Items to be checked or noted include, but are not limited to:

1. Embankments
   a. Erosion gullies in dam embankment
   b. Damage from burrowing animals or vegetation
   c. Displacement or loss of riprap protection
   d. Displacement of fill, sinkholes, slumps, or other items
   e. Any seepage on downstream or base of embankment
2. Gatehouse - Any damage or vandalism
3. Outlet Works
   a. Any differential settlement or movement resulting in cracking of the conduit
   b. Erosion of the seals or concrete by cavitation immediately downstream of the gates
   c. Major seepage of water into the conduit
   d. Major deterioration of exposed concrete due to freeze/thaw cycles or sulfate reactions
   e. Operation of both gates through a full cycle
   f. Free, unobstructed operation of the air vent

g. Corrosion of any metal

h. Proper lubrication and cleaning of the pedestals

i. Jet pump, for unobstructed operation
(see drawing - Appendix E)

4. Spillway
   a. Deterioration of concrete

   b. Separation or movement of joints

   c. Erosion of the spillway chute, backfill behind the walls, or stilling basin

   d. Blockage of the approach or exit channel

RIPRAP INSPECTION

The riprap along the face of the dam should be at least 30 inches thick. Immediately after the occurrence of high water, SWPB personnel will inspect the riprap and determine if additional riprap is necessary.

INSTRUMENTATION

Five monitoring wells were installed in the fall of 2003 along the dam crest. Generally, two piezometers were installed in each monitoring well. Figure 3 shows the general location of the monitoring wells. Soil profiles of the drill holes and details as to how the wells were constructed are shown in Appendix D.

SEEPAGE

Minor seepage has been observed downstream of the toe near the right abutment in the backwater pool. It is unclear whether the water is coming from springs or from bank storage in the gravels around the pool. No indication of sediment moving with the water has been observed.

Seepage of up to about 5 to 10 gallons per minute has been observed seeping from the bedrock joint above and left of the outlet tunnel portal. No indication of sediment moving with the water has been observed. The seepage appears to be directly connected to the reservoir. As the reservoir pool lowers, the seepage decreases.

SEEPAGE MONITORING

The monitoring wells and seepage areas at the dam are observed and monitored by the dam operator, DNRC Helena Regional Office, and SWPB during regular visits; and may be measured by the SWPB during annual inspections.

The instruments are generally measured once per month in March, April, July, August, September, and October; and twice per month in May and June. Measurements may be taken during the winter months (November, December, January, February) depending on weather conditions. The monitoring data is maintained by the SWPB in Helena.

MAINTENANCE

The association is responsible for the routine maintenance of the project. In addition, the SWPB may identify items that need maintenance or repair during the annual inspection

ROUTINE MAINTENANCE

To protect the dam and keep it in good working order, the dam operator during regular visits to the dam will watch for and identify any potential maintenance requirements. As soon as a need is identified, the dam operator needs to schedule and perform the routine maintenance.

Items that may occasionally need attention include, but are not limited to:

1. *Lubrication of gate-operating mechanisms.*
2. *Debris or silt restricting the spillway inlet or the outlet works.* Accumulated debris that could affect the operation of these appurtenances will be removed at once, with all debris removed at least annually.
3. *Erosion gullies on embankment.* Development of erosion gullies will be checked immediately. Gullies will be filled, compacted, and seeded. Particular attention will be paid to the abutment contact areas and the downstream faces where four-wheel drive tracks may become a problem.
4. *Rodent damage.* The rodents will be removed or destroyed, and any burrows holes should be filled immediately.
5. *Upstream slope riprap.* Reservoir riprap normally will be observed annually, but may occasionally need repairs because of high water or wave action.
6. *Vegetative cover on downstream slopes.* Good vegetative cover will be maintained, but large brush will be removed.

7. *Noxious weeds.* Noxious weeds on and around the dam embankment and around the reservoir should be sprayed at least on an annual basis.
8. *Clean concrete structure wall tops.* Spillway and outlet tunnel portal wall tops should be clear of any dirt, rocks, grass, brush, and any overhanging vegetation or trees.
9. *Repair joints and seal crack in the concrete structures.*

ANNUAL MAINTENANCE

The SWPB conducts annual inspections of Willow Creek Dam and Reservoir. During these inspections, any items that require maintenance will be identified and recorded. Items that may need annual maintenance include the spillway, outlet works, gates, riprap, roads, and gatehouse. Any other routine items that need immediate attention, such as the need to remove trees or brush, will also be noted.

After the annual inspection, the SWPB sends the association a Dam Safety Inspection Report and a Maintenance Schedule Report. These reports identify items that need maintenance and provide a schedule of when the maintenance tasks need to be completed. The association is responsible for performing the maintenance items within the times specified.

The dam operator or association members may perform the maintenance tasks. However, major repairs will likely to be handled by a contractor. The SWPB may assist in contracting for repairs and may supervise the repair work.

RECORD KEEPING

The SWPB will maintain records, including photographs, of all inspections and maintenance requirements. These records also include seepage observations. Anyone who wants to review these

records may do so in the SWPB's office at the Department of Natural Resources and Conservation in Helena.

The dam operator will keep records of the reservoir elevation, seepage observations or measurements, and any unusual conditions. These records may be reviewed at the dam operator's house.

,

REFERENCES

CH2M Hill. May 1980. *Phase 1 Inspection Report, National Dam Safety Program, Willow Creek Dam, Willow Creek, Montana, Madison County, MT-22.* Prepared for the State of Montana (DNRC) under the U.S. Army Corps of Engineers' National Dam Safety Program.

Miller, Roy, Willow Creek dam operator. October, 1993.

Omang, R. J. July 1992. *Analysis of the Magnitude and Frequency of Floods and the Peak-Flow Gaging Network in Montana.* Water Resources Investigations Report 92-4048. U. S. Geological Survey.

Personal telephone communications with Jim Beck, Helena Regional Office Engineer, DNRC, Helena.

Shields, R. R., J. R. Knapton, M. K. White, T. M. Brosten, and C. L. Chambers. 1993. *Water Resources Data, Montana, Water Year 1992.* Water Data Report MT-92-1. U.S. Geological Survey.

APPENDICES

APPENDIX A

RATING CURVES AND TABLES

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE
EAST SHORE
WILLOW CREEK RESERVOIR

Pins installed 10/25/2001.
Elevations established with a level from the spillway crest (elevation 4,736 feet) on 10/25/2001.
The 0+00 pin is located upstream of the dam on the east side of the reservoir. The pin is about 25 feet south of a one room cabin along the road which slopes down to the reservoir.
Storage volumes based on 1938 original hand surveys of the reservoir.

DISTANCE	ELEVATION	STORAGE
0+00 TOP	4744.85	
0+00 G/S	4744.66	
1	4744.43	26,529
2	4744.20	26,298
3	4743.97	26,066
4	4743.74	25,833
5	4743.52	25,608
6	4743.29	25,377
7	4743.06	25,145
8	4742.83	24,912
9	4742.60	24,679
10	4742.37	24,447
11	4742.21	24,284
12	4742.05	24,122
13	4741.89	23,961
14	4741.73	23,799
15	4741.57	23,637
16	4741.40	23,465
17	4741.24	23,303
18	4741.08	23,141
19	4740.92	22,979
20	4740.76	22,817
21	4740.65	22,706
22	4740.53	22,584
23	4740.42	22,473
24	4740.30	22,352
25	4740.19	22,240
26	4740.08	22,129
27	4739.96	22,008
28	4739.85	21,896
29	4739.73	21,774
30	4739.62	21,663
31	4739.48	21,522
32	4739.35	21,390
33	4739.21	21,238
34	4739.08	21,117
35	4738.94	20,975
DISTANCE	ELEVATION	STORAGE

DISTANCE	ELEVATION	STORAGE
36	4738.80	20,834
37	4738.67	20,773
38	4738.53	20,661
39	4738.40	20,429
40	4738.26	20,287
41	4738.13	20,155
42	4737.26	19,315
43	4737.09	19,103
44	4736.92	18,931
45	4736.75	18,759
46	4736.59	18,597
47	4736.42	18,425
48	4736.25	18,253
49	4736.08	18,081
SPILLWAY	4736.00	18,000
0+50 CAP	4736.36	18,365
50	4735.91	17,968
51	4735.83	17,865
52	4735.74	17,793
53	4735.66	17,729
54	4735.58	17,665
55	4735.50	17,602
56	4735.41	17,530
57	4735.33	17,466
58	4735.25	17,402
59	4735.16	17,330
60	4735.08	17,267
61	4734.98	17,123
62	4734.88	17,107
63	4734.78	17,028
64	4734.68	16,948
65	4734.58	16,868
66	4734.48	16,789
67	4734.38	16,709
68	4734.28	16,629
69	4734.18	16,549
70	4734.08	16,470
DISTANCE	ELEVATION	STORAGE

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE (continued)

EAST SHORE

WILLOW CREEK RESERVOIR

DISTANCE	ELEVATION	STORAGE
71	4733.96	16,374
72	4733.84	16,279
73	4733.72	16,183
74	4733.60	16,088
75	4733.48	15,992
76	4733.36	15,896
77	4733.24	15,801
78	4733.12	15,706
79	4733.00	15,610
80	4732.88	15,515
81	4732.77	15,427
82	4732.66	15,339
83	4732.55	15,252
84	4732.44	15,162
85	4732.33	15,076
86	4732.22	14,988
87	4732.11	14,901
88	4732.00	14,813
89	4731.89	14,726
90	4731.78	14,638
91	4731.66	14,542
92	4731.55	14,455
93	4731.43	14,359
94	4731.31	14,264
95	4731.20	14,176
96	4731.08	14,081
97	4730.96	13,985
98	4730.84	13,890
99	4730.73	13,802
1+00 CAP	4730.91	13,945
100	4730.61	13,706
101	4730.49	13,611
102	4730.37	13,515
103	4730.25	13,419
104	4730.13	13,324
105	4730.01	13,228
106	4729.89	13,157
107	4729.77	13,145
108	4729.65	13,019
109	4729.53	12,950
110	4729.41	12,882
111	4729.28	12,807
112	4729.15	12,732
113	4729.02	12,657
114	4728.89	12,531
115	4728.76	12,508
DISTANCE	ELEVATION	STORAGE

DISTANCE	ELEVATION	STORAGE
116	4,728.63	12,433
117	4,728.50	12,359
118	4,728.37	12,284
119	4,728.24	12,210
120	4,728.11	12,135
121	4,728.01	12,078
122	4,727.90	12,015
123	4,727.80	11,957
124	4,727.69	11,894
125	4,727.59	11,836
126	4,727.48	11,774
127	4,727.38	11,716
128	4,727.27	11,653
129	4,727.17	11,568
130	4,727.06	11,532
131	4,726.93	11,458
132	4,726.80	11,383
133	4,726.66	11,302
134	4,726.53	11,228
135	4,726.40	11,154
136	4,726.27	11,079
137	4,726.14	11,004
138	4,726.00	10,924
139	4,725.87	10,849
140	4,725.74	10,775
141	4,725.61	10,700
142	4,725.47	10,620
143	4,725.34	10,545
144	4,725.20	10,465
145	4,725.07	10,390
146	4,724.94	10,316
147	4,724.80	10,236
148	4,724.67	10,161
149	4,724.53	10,081
1+50 CAP	4,724.69	10,172
150	4,724.40	10,007
151	4,724.26	9,926
152	4,724.12	9,846
153	4,723.97	9,761
154	4,723.83	9,681
155	4,723.69	9,601
156	4,723.55	9,520
157	4,723.41	9,441
158	4,723.26	9,355
159	4,723.12	9,274
160	4,722.98	9,195
DISTANCE	ELEVATION	STORAGE

TABLE 1. SLOPE-ELEVATION-STORAGE TABLE (continued)

EAST SHORE

WILLOW CREEK RESERVOIR

DISTANCE	ELEVATION	STORAGE	DISTANCE	ELEVATION	STORAGE
161	4722.85	9,120			
162	4722.71	9,041			
163	4722.58	8,967			
164	4722.45	8,892			
165	4722.32	8,817			
166	4722.18	8,738			
167	4722.05	8,646			
168	4721.92	8,589			
169	4721.78	8,509			
170	4721.65	8,434			
171	4721.54	8,372			
172	4721.42	8,303			
173	4721.31	8,241			
174	4721.19	8,172			
1+75 CAP	4721.16	8,154			
175	4721.08	8,109			
176	4720.94	8,029			
177	4720.79	7,943			
178	4720.65	7,862			
179	4720.50	7,777			
DISTANCE	ELEVATION	STORAGE	DISTANCE	ELEVATION	STORAGE

TABLE 2. SLOPE-ELEVATION-STORAGE TABLE
BOAT RAMP
WILLOW CREEK RESERVOIR

The initial point (0+00) is the first horizontal joint below the top of the boat ramp.

Elevations were interpolated using a GPS for the stamped caps, and then for in between points.
GPS Elevations - 10 APRIL 2002
Quick static from dam slope 0+00 cap to TP Z near boat ramp.
Kinematic GPS from the TP Z to named points on slab.

Elevations below 97 feet are estimated and need to be measured.

DISTANCE	ELEVATION	STORAGE	COMMENTS
	4740.87	22959	Top Boat Ramp
	4740.83	22888	
	4740.80	22857	
	4740.76	22806	
0.0	4740.73	22,756	Initial Point
1.0	4740.66	22,756	
2.0	4740.59	22,655	
3.0	4740.52	22,554	
4.0	4740.45	22,504	
5.0	4740.38	22,453	
6.0	4740.31	22,352	
7.0	4740.24	22,250	
8.0	4740.17	22,200	
9.0	4740.09	22,149	
10.0	4740.02	22,048	
11.0	4739.95	21,947	
12.0	4739.88	21,896	
13.0	4739.81	21,845	
14.0	4739.74	21,744	
15.0	4739.67	21,693	
16.0	4739.60	21,643	
17.0	4739.53	21,593	
18.0	4739.46	21,542	
19.0	4739.39	21,441	
20.0	4739.32	21,340	
21.0	4739.25	21,345	
22.0	4739.18	21,238	
23.0	4739.11	21,239	Boat Ramp - iron post
24.0	4739.03	21,036	
25.0	4738.94	20,935	
26.0	4738.86	20,884	
27.0	4738.78	20,833	
28.0	4738.70	20,732	

TABLE 2. SLOPE-ELEVATION-STORAGE TABLE
BOAT RAMP
WILLOW CREEK RESERVOIR

DISTANCE	ELEVATION	STORAGE	COMMENTS
29.0	4738.61	20,631	
30.0	4738.53	20,530	
31.0	4738.45	20,480	
32.0	4738.36	20,429	
33.0	4738.28	20,328	
34.0	4738.20	20,226	
35.0	4738.11	20,125	
36.0	4738.03	20,024	
37.0	4737.95	19,923	
38.0	4737.86	19,872	
39.0	4737.78	19,821	
40.0	4737.70	19,750	
41.0	4737.62	19,619	
42.0	4737.53	19,518	
43.0	4737.45	19,468	
44.0	4737.37	19,417	
45.0	4737.28	19,316	
46.0	4737.20	19,214	
47.0	4737.12	19,113	
48.0	4737.03	19,012	
49.0	4736.95	18,962	
50.0	4736.87	18,911	Boat Ramp - horizontal joint
51.0	4736.77	18,809	
52.0	4736.68	18,708	
53.0	4736.58	18,607	
54.0	4736.48	18,506	
55.0	4736.39	18,405	
56.0	4736.29	18,304	
57.0	4736.19	18,202	
58.0	4736.10	18,101	
59.0	4736.00	18,000	Boat Ramp - cap 4736 Spillway Crest Elevation
60.0	4735.86	17,920	
61.0	4735.71	17,761	
62.0	4735.57	17,681	
63.0	4735.43	17,522	
64.0	4735.29	17,442	
6[illegible].0	4735.14	17,283	
66.0	4735.00	17,203	Boat Ramp - cap xxxx
67.0	4734.87	17,123	
68.0	4734.73	16,964	
69.0	4734.60	16,882	
70.0	4734.47	16,805	
70.5	4734.40	16,725	Boat Ramp - brass plate
71.0	4734.33	16,645	
72.0	4734.20	16,565	
73.0	4734.07	16,486	

TABLE 2. SLOPE-ELEVATION-STORAGE TABLE
BOAT RAMP
WILLOW CREEK RESERVOIR

DISTANCE	ELEVATION	STORAGE	COMMENTS
73.5	4734.00	16,406	Boat Ramp - cap 473x (4)
74.0	4733.94	16,326	
75.0	4733.81	16,247	
76.0	4733.69	16,167	
77.0	4733.56	16,088	
78.0	4733.44	15,928	
78.5	4733.38	15,888	Boat Ramp - brass plate
79.0	4733.31	15,849	
80.0	4733.19	15,769	
81.0	4733.06	15,690	
81.5	4733.00	15,610	Boat Ramp - cap 4733
82.0	4732.93	15,530	
83.0	4732.80	15,451	
83.5	4732.73	15,411	Measured here 5/3/2002. 0.9 Stick up at 4732 Cap
84.0	4732.67	15,371	
85.0	4732.53	15,212	
86.0	4732.40	15,132	
86.5	4732.33	15,092	Boat Ramp - brass plate
87.0	4732.27	15,052	
88.0	4732.13	14,893	
89.0	4732.00	14,813	Boat Ramp - cap 4732
90.0	4731.88	14,733	
91.0	4731.75	14,654	
91.5	4731.69	14,575	Boat Ramp - water edge
92.0	4731.63	14,495	
93.0	4731.50	14,415	
94.0	4731.38	14,335	
94.5	4731.31	14,296	Boat Ramp - brass plate
95.0	4731.25	14,256	
96.0	4731.13	14,097	
97.0	4731.00	14,017	Boat Ramp - 4731
98.0	4730.88	13,937	
98.0	4730.75	13,858	
100.0	4730.63	13,698	
101.0	4730.50	13,619	
102.0	4730.38	13,539	Boart Ramp - ground surface
103.0	4730.25	13,459	
104.0	4730.13	13,300	
105.0	4730.00	13,220	Boat Ramp - 4730
106.0	4729.89	13,163	
107.0	4729.77	13,105	
108.0	4729.66	13,048	
109.0	4729.54	12,933	
110.0	4729.43	12,876	
110.5	4729.37	12,847	Boat Ramp - brass plate
111.0	4729.32	12,818	

TABLE 2. SLOPE-ELEVATION-STORAGE TABLE
BOAT RAMP
WILLOW CREEK RESERVOIR

DISTANCE	ELEVATION	STORAGE	COMMENTS
112.0	4729.20	12,761	
113.0	4729.09	12,703	Boat Ramp - horizontal joint
114.0	4728.98	12,648	
115.0	4728.86	12,589	
116.0	4728.75	12,531	
117.0	4728.63	12,433	
118.0	4728.52	12,359	Boat Ramp - bubble deep

TABLE 3. TOTAL STORAGE CAPACITY IN ACRE-FEET

WILLOW CREEK RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
4666						269	271	273	274	276
4667	278	280	282	284	286	288	289	291	293	295
4668	297	299	301	303	305	307	308	310	312	314
4669	316	318	320	322	324	326	327	329	331	333
4670	335	338	340	343	345	348	351	353	356	358
4671	361	364	366	369	371	374	377	379	382	384
4672	387	390	392	395	397	400	403	405	408	410
4673	413	416	418	421	423	426	429	431	434	436
4674	439	442	444	447	449	452	455	457	460	462
4675	465	468	472	475	478	482	485	488	491	495
4676	498	501	505	508	511	515	518	521	524	528
4677	531	534	538	541	544	548	551	554	557	561
4678	564	567	571	574	577	581	584	587	590	594
4679	597	600	604	607	610	614	617	620	623	627
4680	630	634	639	643	648	652	656	661	665	670
4681	674	678	683	687	691	696	700	704	708	713
4682	717	721	726	730	734	739	743	747	751	756
4683	760	764	769	773	777	782	786	790	794	799
4684	803	807	812	816	820	825	829	833	837	842
4685	846	851	856	862	867	872	877	882	888	893
4686	898	903	909	914	919	925	930	935	940	946
4687	951	956	961	967	972	977	982	987	993	998
4688	1,003	1,008	1,014	1,019	1,024	1,030	1,035	1,040	1,045	1,051
4689	1,056	1,061	1,067	1,072	1,078	1,083	1,088	1,094	1,099	1,105
4690	1,110	1,117	1,124	1,130	1,137	1,144	1,151	1,158	1,164	1,171
4691	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227	1,234	1,241
4692	1,248	1,255	1,262	1,269	1,276	1,283	1,290	1,297	1,304	1,311
4693	1,318	1,325	1,332	1,339	1,346	1,353	1,360	1,367	1,374	1,381
4694	1,388	1,395	1,402	1,410	1,417	1,424	1,431	1,438	1,446	1,453
4695	1,460	1,469	1,478	1,488	1,497	1,506	1,515	1,524	1,534	1,543
4696	1,552	1,561	1,570	1,580	1,589	1,598	1,607	1,616	1,626	1,635
4697	1,644	1,653	1,662	1,672	1,681	1,690	1,699	1,708	1,718	1,727
4698	1,736	1,745	1,754	1,764	1,773	1,782	1,791	1,800	1,810	1,819
4699	1,828	1,837	1,846	1,856	1,865	1,874	1,883	1,892	1,902	1,911
4700	1,920	1,932	1,945	1,957	1,970	1,982	1,994	2,007	2,019	2,032
4701	2,044	2,056	2,069	2,081	2,094	2,106	2,118	2,131	2,143	2,156
4702	2,168	2,180	2,193	2,205	2,218	2,230	2,242	2,255	2,267	2,280
4703	2,292	2,304	2,317	2,329	2,342	2,354	2,366	2,379	2,391	2,404
4704	2,416	2,428	2,441	2,453	2,466	2,478	2,490	2,503	2,515	2,528
4705	2,540	2,559	2,578	2,597	2,616	2,636	2,655	2,674	2,693	2,712
4706	2,731	2,750	2,769	2,789	2,808	2,827	2,846	2,865	2,885	2,904
4707	2,923	2,942	2,961	2,980	2,999	3,019	3,038	3,057	3,076	3,095
4708	3,114	3,133	3,152	3,172	3,191	3,210	3,229	3,248	3,268	3,287
4709	3,306	3,325	3,344	3,363	3,382	3,402	3,421	3,440	3,459	3,478
4710	3,497	3,536	3,574	3,613	3,651	3,690	3,729	3,767	3,806	3,844

TABLE 3. TOTAL STORAGE CAPACITY IN ACRE-FEET (continued)
WILLOW CREEK RESERVOIR

Elevation	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
4711	3,883	3,922	3,960	3,999	4,037	4,076	4,114	4,153	4,191	4,230
4712	4,268	4,307	4,345	4,384	4,422	4,461	4,500	4,538	4,577	4,615
4713	4,654	4,693	4,731	4,770	4,808	4,847	4,885	4,924	4,962	5,001
4714	5,039	5,078	5,116	5,155	5,193	5,232	5,271	5,309	5,348	5,386
4715	5,425	5,466	5,508	5,549	5,590	5,632	5,673	5,714	5,755	5,797
4716	5,838	5,889	5,941	5,992	6,043	6,095	6,146	6,197	6,248	6,300
4717	6,351	6,392	6,434	6,475	6,517	6,558	6,599	6,641	6,682	6,724
4718	6,765	6,806	6,848	6,889	6,930	6,972	7,013	7,054	7,095	7,137
4719	7,178	7,209	7,241	7,272	7,303	7,335	7,366	7,397	7,428	7,460
4720	7,491	7,548	7,605	7,663	7,720	7,777	7,834	7,891	7,949	8,006
4721	8,063	8,120	8,177	8,235	8,292	8,349	8,406	8,463	8,521	8,578
4722	8,635	8,692	8,749	8,806	8,863	8,921	8,978	9,035	9,092	9,149
4723	9,206	9,263	9,320	9,378	9,435	9,492	9,549	9,606	9,664	9,721
4724	9,778	9,835	9,892	9,950	10,007	10,064	10,121	10,178	10,236	10,293
4725	10,350	10,407	10,465	10,522	10,580	10,637	10,694	10,752	10,809	10,867
4726	10,924	10,981	11,039	11,096	11,154	11,211	11,268	11,326	11,383	11,441
4727	11,498	11,555	11,613	11,670	11,728	11,785	11,842	11,900	11,957	12,015
4728	12,072	12,129	12,187	12,244	12,302	12,359	12,416	12,474	12,531	12,589
4729	12,646	12,703	12,761	12,818	12,876	12,933	12,990	13,048	13,105	13,163
4730	13,220	13,300	13,379	13,459	13,539	13,619	13,698	13,778	13,858	13,937
4731	14,017	14,097	14,176	14,256	14,335	14,415	14,495	14,574	14,654	14,733
4732	14,813	14,893	14,972	15,052	15,132	15,212	15,291	15,371	15,451	15,530
4733	15,610	15,690	15,769	15,849	15,928	16,008	16,088	16,167	16,247	16,326
4734	16,406	16,486	16,565	16,645	16,725	16,805	16,884	16,964	17,044	17,123
4735	17,203	17,283	17,362	17,442	17,522	17,602	17,681	17,761	17,841	17,920
4736	18,000	18,101	18,202	18,304	18,405	18,506	18,607	18,708	18,810	18,911
4737	19,012	19,113	19,214	19,316	19,417	19,518	19,619	19,720	19,822	19,923
4738	20,024	20,125	20,226	20,328	20,429	20,530	20,631	20,732	20,834	20,935
4739	21,036	21,137	21,238	21,340	21,441	21,542	21,643	21,744	21,846	21,947
4740	22,048	22,149	22,250	22,352	22,453	22,554	22,655	22,756	22,858	22,959
4741	23,060	23,161	23,262	23,364	23,465	23,566	23,667	23,768	23,870	23,971
4742	24,072	24,173	24,274	24,376	24,477	24,578	24,679	24,780	24,882	24,983
4743	25,084	25,185	25,286	25,388	25,489	25,590	25,691	25,792	25,894	25,995
4744	26,096	26,197	26,298	26,398	26,499	26,600				

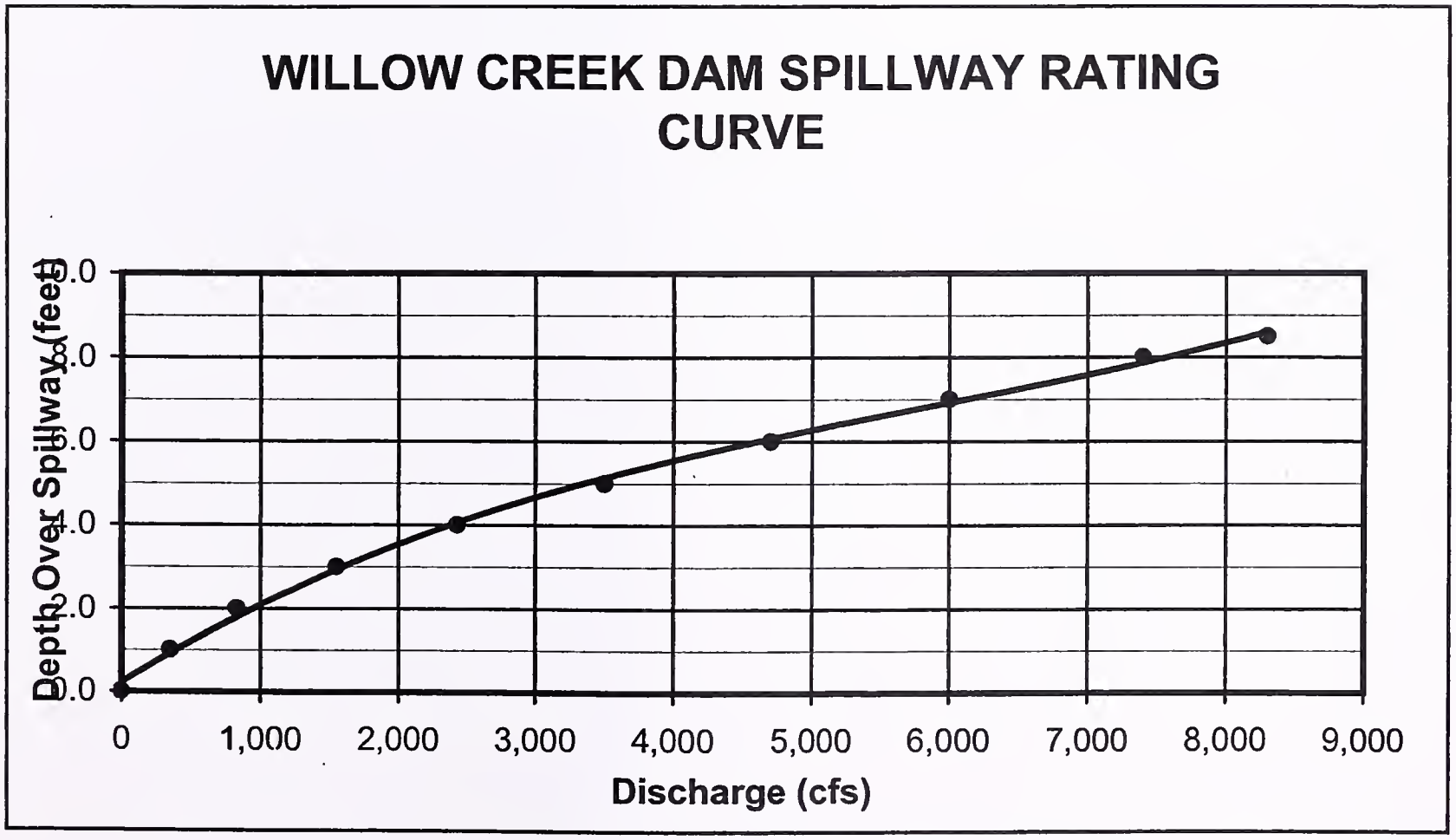
NOTE: Storage table based on 1938 original hand surveys of the reservoir.
Table prepared 4/19/01 by Bob Arrington based on 1995 O&M storage table.
Storage volume includes dead storage of 269 acre-feet.

Spillway crest	Elevation 4,736 feet	Storage 18,000 acre-feet
Dam Crest	Elevation 4,744.5 feet	Storage 26,600 acre-feet

TABLE 4. SPILLWAY DISCHARGE

WILLOW CREEK RESERVOIR

Depth Over Crest (feet)	Elevation (feet)	Discharge (cfs)
0.0	4,736.0	0
1.0	4,737.0	350
2.0	4,738.0	830
3.0	4,739.0	1,550
4.0	4,740.0	2,430
5.0	4,741.0	3,500
6.0	4,742.0	4,700
7.0	4,743.0	6,000
8.0	4,744.0	7,400
8.5	4,744.5	8,300



Note: Data from the Corps of Engineers Phase 1 Inspection Report (1980).

APPENDIX B

INSPECTION REPORT FORM

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
DAM SAFETY INSPECTION REPORT

NAME OF DAM
DATE INSPECTED

INVENTORY NO. _____ OWNER _____
HAZARD CATEGORY _____ OPERATOR _____
TYPE OF DAM _____ STREAM _____
YEAR BUILT _____ DRAINAGE AREA _____

Reservoir Storage Status

	Water Surface Elevation (feet)	Storage (acre-feet)
At time of inspection	_____	_____
At spillway crest	_____	_____
At min. dam crest elevation	_____	_____

ITEM	YES	NO	REMARKS
1. EMBANKMENT			
A. Crest -- Height= Length= Width=			
(1) Any visual settlements?			
(2) Any misalignments?			
(3) Any cracking?			
(4) Any traffic damage?			
(5) Other?			

ITEM	YES	NO	REMARKS

1. EMBANKMENT (continued)

B. Upstream Face -- Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Is riprap protection adequate?			
(5) Any stone deterioration?			
(6) Any visual settlement, slumps, sloughing, depressions or bulges?			
(7) Adequate grass cover?			
(8) Debris on the dam face?			
(9) Other?			

C. Downstream Face--Slope=

(1) Any erosion?			
(2) Any longitudinal cracks?			
(3) Any transverse cracks?			
(4) Any visual settlement, slumps, sloughing, depressions or bulges?			
(5) Is the toe drain dry?			
(6) Are the relief wells flowing?			
(7) Any boils at the toe?			
(8) Any seepage areas?			
(9) Any traffic or animal damage?			
(10) Any burrowing animals?			
(11) Adequate grass cover?			
(12) Other?			

D. Amount and Type of Vegetation on the Dam

.

ITEM	YES	NO	REMARKS

2. ABUTMENT CONTACTS

A) Any erosion?			
B) Any visual differential movement?			
C) Any cracks?			
D) Any seepage present?			
E) Other?			

3. OUTLET WORKS

A. Intake Structure -- Size=

(1) Any settlement?			
(2) Any tilting?			
(3) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(4) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(5) Metal appurtenances:			
a. Any corrosion present?			
b. Any breakage present?			
(6) Trash rack?			
a. Condition?			
b. Anchor system secure?			
(7) Other?			

ITEM	YES	NO	REMARKS

3. **OUTLET WORKS** (continued)

B. Conduit – Type = Size =

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
c. Leakage?			
(3) Is the conduit metal?			
a. Any corrosion present?			
b. Protective coatings adequate?			
(4) Is the conduit misaligned?			
(5) Any calcium deposits?			
(6) Other?			

C. Gates and Tower

(1) Gates:			
a. Size: Operating: Emergency: b. Type: Operating: Emergency:			
(2) Controls operational?			
(3) Controls lubricated?			
(4) Operational problems?			
(5) Leakage around gates?			
(6) Condition of gate seals?			
(7) Any cavitation damage? If so, describe?			
(8) Describe air vent-size and condition.			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

C. Gates and Tower (continued)

(9) Is there a jet pump?			
a. Is it operational?			
b. Leakage?			
(10) Is the tower dry? ____ wet?			
(11) Any seepage in the tower?			
(12) Condition of the tower?			
(13) Any safety problems?			
(14) Ladder in good condition?			
(15) Condition of the gatehouse?			
(16) Emergency plan completed for the dam?			
a. Posted in the gatehouse?			
(17) Other?			

D. Stilling Basin

(1) Do concrete surfaces show:			
a. Spalling?			
b. Cracking?			
c. Erosion?			
d. Exposed reinforcement?			
(2) Do joints show:			
a. Displacement or offset?			
b. Loss of joint material?			
b. Leakage?			
(3) Do energy dissipaters show:			
a. Signs of deterioration?			
b. Are they covered with debris?			
(4) Other?			

ITEM	YES	NO	REMARKS

3. OUTLET WORKS (continued)

E. Downstream Channel

(1) Is the channel:			
a. Eroding or backcutting?			
b. Sloughing?			
c. Obstructed?			
(2) Is released water:			
a. Undercutting the outlet?			
b. Eroding the embankment?			
(3) Other?			

4. SPILLWAY

A. Description

(1) Location?			
(2) Type of Spillway?			
(3) Size of Spillway?			
(4) Spillway lining?			
(5) Is there a weir?			
(6) Is the spillway in good condition?			
(7) Any drains?			
a. Describe the condition of drains.			

B. Does spillway show:

(1) Any cracking concrete?			
(2) Any spalling concrete?			
(3) Any exposed reinforcement in the concrete?			
(4) Any erosion?			

ITEM	YES	NO	REMARKS

4. SPILLWAY (continued)

4. B. Does spillway show: (continued)

(5) Any slope sloughing?			
(6) Any obstructions?			
(7) Displacement or offset joints?			
(8) Loss of joint material?			
(9) Leakage at the joints?			
(10) Other?			

C. Do the energy dissipaters show:

(1) Signs of deterioration?			
(2) Any cracking?			
(3) Any spalling?			
(4) Any exposed reinforcement?			
(5) Are they covered with debris?			
(6) Other?			

D. Has release water:

(1) Eroded the embankment?			
(2) Undercut the outlet?			
(3) Eroded the downstream channel?			
(4) Other?			

E. Emergency Spillway

(1) Is there an emergency spillway?			(If YES, describe)

ITEM	YES	NO	REMARKS

5. RESERVOIR CONTROL

A) Recent upstream development?			
B) Recent downstream development?			
C) Slides in reservoir area?			
D) Change in reservoir operation?			
E) Large impoundment upstream?			
F) Any debris in the reservoir?			
G) Other?			

6. INSTRUMENTATION

A) List type(s) of instrumentation:			
B) In good condition?			
C) Read periodically?			
D) Is data available?			
E) Include all data gathered since last report.			

7. DOWNSTREAM CONDITION

A. Downstream Land Use.

This dam was inspected by:

Additional comments and recommendations.

APPENDIX C

DISTRIBUTION LIST

O&M MANUAL DISTRIBUTION LIST

WILLOW CREEK DAM

		Number Of Copies
1.	State Water Projects Bureau Kevin Smith Rob Kingery Dirk Robert (2) Bob Arrington Delores Eustice	6
2.	DNRC Information Services Section	1
3.	DNRC Bozeman and Helena Regional Office Scott Compton Jim Beck	2
4.	DNRC Dam Safety	1
5.	Water Users LeRoy Miller -- President Robert C. Rice -- Vice President Mary Miller -- Secretary/Treasure Lezlie Kinne -- Dam Operator Copy for Gatehouse	5
6.	State Library -- Attn: Roberta Gebhardt	4
7.	Extra	2
TOTAL		21

APPENDIX D

MONITORING WELL LOGS

D2 2005

SOIL LOG OF BOREHOLE NO: DH1

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 9/29/2003	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/1/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4746.2	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	4746		0 to 2' ROAD BASE gravelly sand, brown, subangular gravel fragments, dry to slightly moist	GP								
5	4741	☒	2 to 42.5' SANDY CLAY, brown, slightly moist to moist (moisture increasing with depth), meduium stiff, low plasticity			SL	3 8 10	22	15/18	83%	4	
10	4736	☒				SS	3 5 5	11	9/18	50%		12.5 to13 ' Rock fragments
15	4731	☒		CL		SL	1 8 10	14	12/18	66%	2.5	
20	4726	☒				SS	3 3 5	8	18/18	100%		
25	4721	☒				SL	6 8 11	13	16/18	89%	2.5	25 to 25.5' % Finer #200 = 61% m = 18.9% Dry Unit Weight = 104.6 pcf
30	4716	☒				SS	3 6 4	8	12/18	66%	2.5	
35		☒	soil sample taken from 34 to 35.5'			SL	2 4 5	6	16/18	89%	2.5	34.5' m = 18.9 Dry Unit Weight = 104.6 pcf Nondispersive

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3 2 1/2" core diameter
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

08-29-2003 ATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-1 Soil.bor

SOIL LOG OF BOREHOLE NO: DH1

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 9/29/2003	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/1/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4746.2	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Counts (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
35	4711			CL		SS	2 4 4	6	18/18	100%		39.0 to 40.5' % Finer #200 = 60% LL=26% PL=16% PI=10%
40	4706		42.5 to 44' ROCKY DEBRIS	ME								43' Bedrock contact
45	4701		44 to 66.7' GNEISS, quartzo-feldspathic, white and black banded, foliated and jointed at 40 degrees to core axis			SS	50+		0/18	0%		Cored 44 to 48.2' RQD = 38% Recovery = 90%
50	4696											Cored 48.2 to 53.2' RQD = 77% Recovery = 100%
55	4691			ME								Cored 53.2 to 58.2' RQD = 68% Recovery = 100%
60	4686											Cored 58.2 to 63.2' RQD = 53% Recovery = 100%
65	4681											63.2 to 66.7' RQD = 29% Recovery = 100%
70			66.7' BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3 2 1/2" core diameter
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-1 Soil.bor

WELL COMPLETION LOG NO: DH1

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 9/29/2003	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/1/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles
DRILLER	: Bill Neff	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 4746.2

0 — 4746
5 — 4741
10 — 4736
15 — 4731
20 — 4726
25 — 4721
30 — 4716
35 — 4711
40 — 4706
45 — 4701
50 — 4696
55 — 4691
60 — 4686
65 — 4681
70

Well Construction Information

WELL CONSTRUCTION

Date Compl. : 10/1/2003
Hole Diameter : 8 inch
DNRC Rep. : Craig Stiles

STANDPIPE

Material : PVC pipe
Diameter : 1 inch
Joints : screwed
Bottom Cap : screwed

WELL SCREEN

Material : PVC pipe
Diameter : 1 inch
Length : 5 feet
Opening : .02 inch

SAND PACK

Material : Colorado Silica 10/20

ANNULUS

Material : 3/8 inch Bentonite

WELL COVER

Dimentions : 4 x 4 inch square
Length : 5 feet

NOTES:

Location: Left Abutment
Downstream side of crest
Near gatehouse

Surface Elev: 4746.20 feet

DH1A TOP Elev: 4747.9 feet

DH1B TOP Elev: 4747.89 feet

Top of Cover Elev: 4748.21 feet

Northing:

Easting:

Surveyed By: Bob Arrington and Craig Stiles

Date Surveyed: 10/2003

DESCRIPTION

0 to 3 SAND

3 to 31 BENTONITE

31 to 41 SAND

34 to 39 SCREEN FOR DH1B

41 to 45 BENTONITE

44 Bedrock Contact

45 to 64.7 NATIVE MATERIAL (Caved)

59.7 to 64.7 SCREEN FOR DH1A

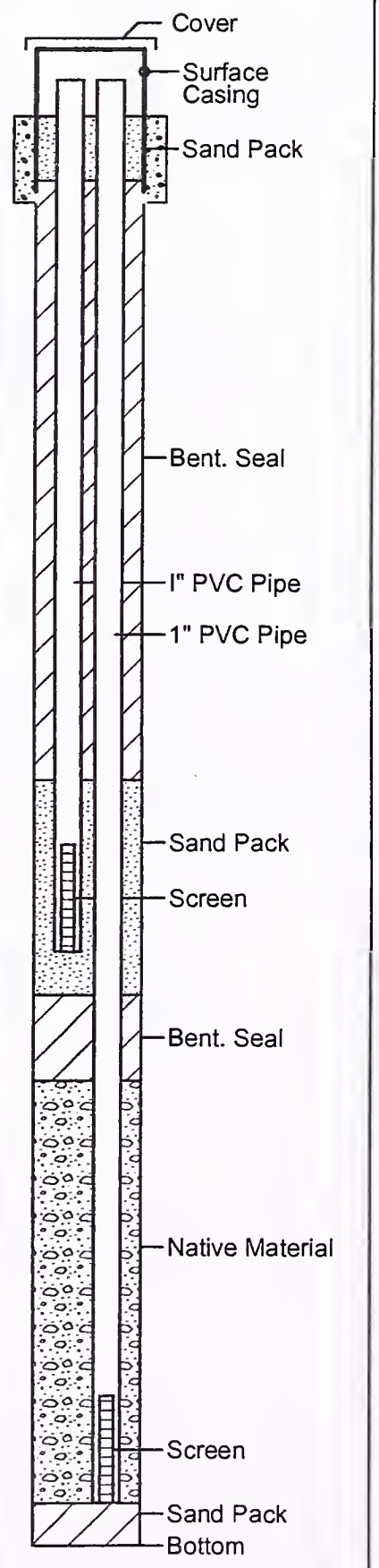
64.7 to 66.7 SAND

66.7 BOTTOM OF HOLE

Depth In Feet

0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

Well1: DH-1A
Well2: DH-1B



08-29-2005 C:\WATER_PRI\PROJECTS\Bob A\Well Logs\Willow\Willow DH-1 WC.bor

SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/1/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/6/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles-Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.3	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	4745		0 to 2' ROAD BASE gravelly sand, brown, subangular gravel fragments, dry to slightly moist	GP								
			2 to 89' SANDY CLAY, brown, slightly moist to moist (moisture increasing with depth), meduium stiff, low plasticity			SS	2 5 7	19	6/18	33%		4 to 5.5' Sample - dry
5	4740											
10	4735					SL	7 7 7	12	9/18	50%	2.0	
15	4730			CL		SS	2 7 8	15	16/18	89%		
20	4725					SL	3 8 15	19	14/18	78%	1.75	
25	4720					SS	4 5 9	12	16/18	89%		24 to 25.5' Sample - gray brown
30			soil sample taken from 29 to 30.5'			SL	3 5 11	11	16/18	89%	1.25	29 to 30.5' Sample - dark gray brown

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-2 Soil.bor

SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/1/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/6/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles-Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.3	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	4715											30' % Finer #200 = 54%
35	4710	X				ST			24/24	100%		34 to 36' % Finer #200 = 46% m = 21% Dry Unit Weight = 105.9 pcf
40	4705	X				SL	5 9 10	11			.75	
45	4700	X		CL		SS	1 2 3	3	18/18	100%		44 to 45.5' Sample - very moist Installed upper screen at this location % Finer #200 - 64%
50	4695	X				SL	2 7 8	9	15/18	83%	1.5	49 to 50.5' Torvane = 6.5 tsf
55	4690	X				SS	3 6 9	10	16/18	89%		54 to 55.5' Sample - very moist, water likely seeping in to borehole
60		X	soil sample taken from 59 to 60.5'			SL	5 8 7	8	15/18	83%	+4.5	

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 ...ATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-2 Soil.bor

SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/1/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/6/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles-Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.3	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
60	4685											
65	4680					ST			13/24	54%		
70	4675					SS	2 5 5	126	18/18	100%		
75	4670			CL		SL	4 10 15	812	15/18	83%	3.25	74 to 75.5' Sample - included one piece of bedrock - gneiss, blackish Torvane = 1.75 tsf
80	4665					SS	2 4 10	98	18/18	100%		
85	4660					SL	3 8 12	169	15/18	83%	2.75	84.5 to 85' % Finer #200 = 65% Dry Unit Weight = 108.5 LL=26% PL=17% PI=9% Torvane = 6.0 tsf 89 to 90.5' Sample - included some rock pieces, more sand, gneiss at 90.5' - blackish, very decomposed - likely bedrock interface
90			89' BOTTOM OF HOLE			SS	3 8 20	16	15/18	83%		

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-2 Soil.bor

WELL COMPLETION LOG NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/1/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/6/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles-Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 4745.3

Well Construction Information

WELL CONSTRUCTION

Date Compl. : 10/6/2003
Hole Diameter : 8 inch
DNRC Rep. : Craig Stiles

STANDPIPE

Material : PVC pipe
Diameter : 1 inch
Joints : screwed
Bottom Cap : screwed

WELL SCREEN

Material : PVC pipe
Diameter : 1 inch
Length : 5 feet
Opening : .02 inch

SAND PACK

Material : Colorado Silica 10/20

ANNULUS

Material : 3/8 inch Bentonite

WELL COVER

Dimentions : 4 x 4 inch square
Length : 5 feet

NOTES:

Location: Middle of Dam
Upstream side of crest

Surface Elev: 4745.27 feet

DH2A TOP Elev: 4747.9 feet

DH2B TOP Elev: 4747.99 feet

Top of Cover Elev: 4748.16 feet

Northing:

Easting:

Surveyed By: Bob Arrington and Craig Stiles

Date Surveyed: 10/2003

DESCRIPTION

0 to 3 SAND

3 to 38 BENTONITE

38 to 49 SAND

42 to 47 SCREEN FOR DH2B

49 to 79 BENTONITE

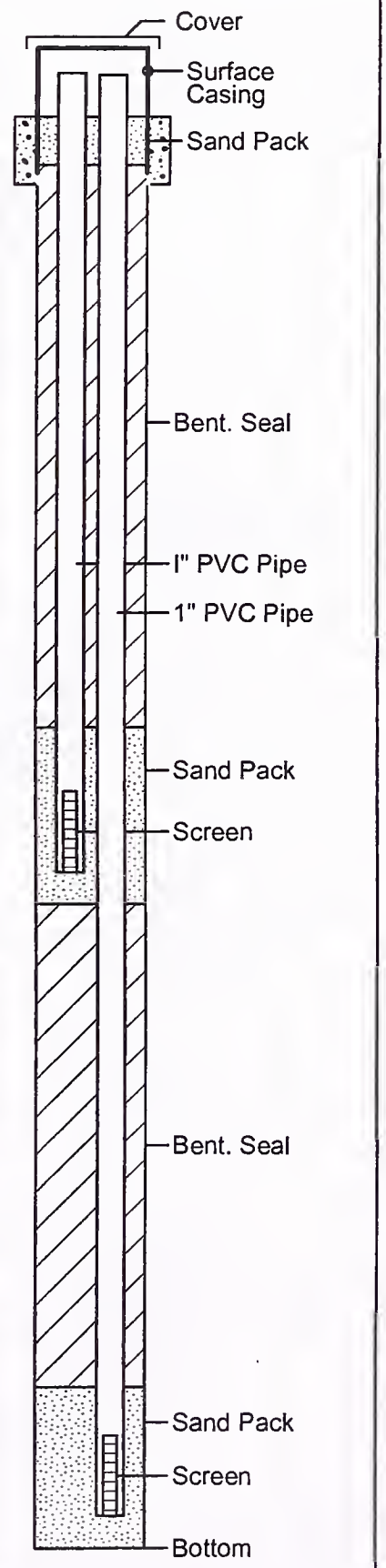
79 to 89 SAND

82 to 87 SCREEN FOR DH2A

89 BOTTOM OF HOLE
(Bedrock Contact)

Depth In Feet

Well1: DH-2A
Well2: DH-2B



08-29-2005 S:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-2 WC.bor

SOIL LOG OF BOREHOLE NO: DH3

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/8/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/9/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Craig Stiles-Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.1	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	4745		0 to 2' ROAD BASE gravelly sand, brown, subangular gravel fragments, dry to slightly moist	GP								
		☒	2 to 13' SANDY CLAY, brown, slightly moist to moist (moisture increasing with depth), meduium stiff, low plasticity	CL		SS	1 4 5	14	12/18	66%		4 to 5.5' Sample - dry
5	4740											
10	4735	☒				SL	4 8 9	15	14/18	78%	1.25	9 to 10.5' Torvane = 2.5 tsf 9.5 to 10' % Finer #200 = 58%
15	4730	☒	13 to 33' GRAVELLY SAND, brown, slightly moist to moist (moisture increasing with depth), gravel fragments up to 1.5", interspersed layers of sandy silt	GM		SS	8 20 12	33	10/18	56%		13 to 19' Cuttings - sandy silt with 30% Gneiss gravel up to 2"
20	4725	☒				SL	7 7 16	19	15/18	83%		19.5 to 20.5' % Finer #200 = 20%
25	4720	☒				SS	14 7 7	27	10/18	56%		24 to 26' Cuttings - moist sandy silt with some gravel (<5%)
30	4715	☒				SL	9 14 13	17	13/18	72%		29.5 to 30' % Finer #200 = 7% m = 6.3% Dry Unit Weight = 120.8 pcf
		☒				SS	27 12 10	18	2/18	11%		33' Refusal - appear to be on a large rock
35			33' BOTTOM OF HOLE									

Hollow Stem Auger 4 !/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-3 Soil.bor

WELL COMPLETION LOG NO: DH3

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/8/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/9/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington-Craig Stiles
DRILLER	: Bill Neff	APPROVED BY	: Kevin Smith

Depth In Feet	Surf. Elev. 4745.1
0	4745
5	4740
10	4735
15	4730
20	4725
25	4720
30	4715
35	

Well Construction Information

WELL CONSTRUCTION

Date Compl. : 10/9/2003
Hole Diameter : 8 inch
DNRC Rep. : Bob Arrington

STANDPIPE

Material : PVC pipe
Diameter : 2 inch
Joints : screwed
Bottom Cap : screwed

WELL SCREEN

Material : PVC pipe
Diameter : 2 inch
Length : 5 feet
Opening : .02 inch

SAND PACK

Material : Colorado Silica 10/20

ANNULUS

Material : 3/8 inch Bentonite

WELL COVER

Dimentions : 4 x 4 inch square
Length : 5 feet

NOTES:

Location: Middle of Dam
Downstream side of crest

Surface Elev: 4745.14 feet

DH3 TOP Elev: 4748.25 feet

Top of Cover Elev:

Northing:

Easting:

Surveyed By: Bob Arrington and Craig Stiles

Date Surveyed: 10/2003

DESCRIPTION

0 to 5 SAND

5 to 14 NATIVE MATERIAL (cuttings)

14 to 23.6 BENTONITE

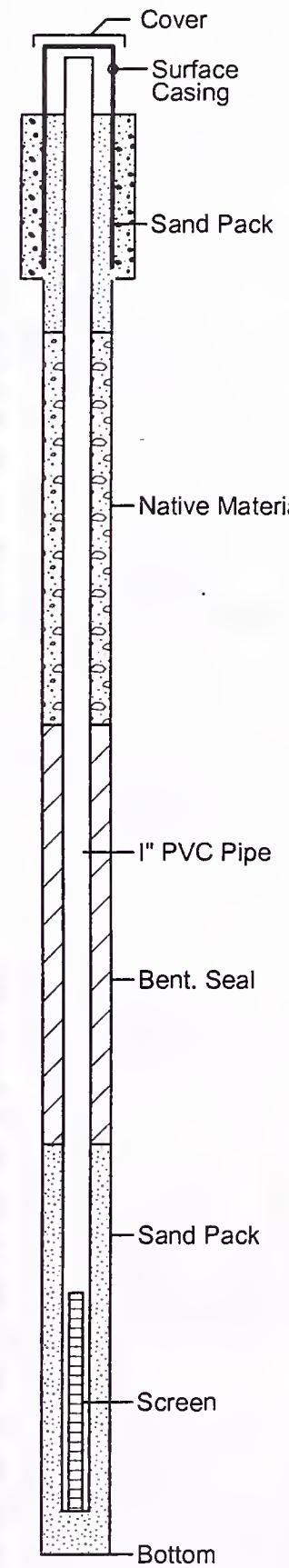
23.6 to 33 SAND

27 to 32 SCREEN FOR DH3

BOTTOM OF HOLE

Depth In Feet
0
5
10
15
20
25
30
35

Well: DH-3



08-29-2005 S:\WATER_PRI\PROJECTS\Bob A\Well Logs\Willow\Willow DH-3 WC.bor

SOIL LOG OF BOREHOLE NO: DH4

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/8/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.4	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	4745		0 to 2' ROAD BASE gravelly sand, brown, subangular gravel fragments, dry to slightly moist	GP								
			2 to 58' SANDY CLAY/SANDY SILT, brown, slightly moist to moist (moisture increasing with depth), meduium stiff, low plasticity									
5	4740	X				SS	3 4 6	17	17/18	94%		
10	4735	X				SL	5 9 11	18	14/18	78%	24.5	
15	4730	X		CL		SS	3 5 7	12	14/18	78%		14 to 16' % Finer #200 = 66% LL=23% PL=19% PI=4% ** After completing DH4, offset 5' to right to get a Shelby sample. Drilled to 14' and then took sample from 14 to 16'.
20	4725	X				SL	3 6 13	15	16/18	89%	1.8	19 to 20.5' Sample - contained few small 1/4" gravel pieces
25	4720	X				SS	2 6 10	14	14/18	78%		24 to 25.5' Sample - contained few small 1/4" gravel pieces
30		X				SL	8 30 23	37	11/18	61%	2.9	29 to 30.5' Sample - contained few small 1/4" gravel pieces, incresed sand particle size

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-4 Soil.bor

SOIL LOG OF BOREHOLE NO: DH4

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/8/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.4	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	4715											30' % Finer #200 = 58%
35	4710	X				SS	3 6 5	9	24/24	100%		
40	4705	X				SL	3 8 10	10	16/18	89%	3.75	40' % Finer #200 = 43%
45	4700	X		CL		SS	2 5 5	7	18/18	100%		44 to 45.5' Sample - yellowish brown to brown
50	4695	X				SL	0 3 8	6	18/18	100%	0.85	50' % Finer #200 = 47% LL=2.4% PL=15.2% PI=15.8% m = 8.2% Dry Unit Weight = 133.5 pcf
55	4690	X				SS	0 4 3	4	18/18	100%		54 to 55.5' Sample - black organic for 3 to 4" then transition to brown % Finer #200 = 61%
60		X	58' BOTTOM OF HOLE			SS	50+		1/18	6%		58 to 59.5' Refusal of 50 blows for approx. 2". Sample - one piece of bedrock - gneiss, black with white striations. Assume bedrock interface.

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 ...ATER_PRI\PROJECTS\Bob A\Well Logs\Willow\Willow DH-4 Soil.bor

WELL COMPLETION LOG NO: DH4

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/8/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 4745.4

Well Construction Information

WELL CONSTRUCTION

Date Compl. : 10/8/2003
Hole Diameter : 8 inch
DNRC Rep. : Bob Arrington

STANDPIPE

Material : PVC pipe
Diameter : 1 inch
Joints : screwed
Bottom Cap : screwed

WELL SCREEN

Material : PVC pipe
Diameter : 1 inch
Length : 5 feet
Opening : .02 inch

SAND PACK

Material : Colorado Silica 10/20

ANNULUS

Material : 3/8 inch Bentonite

WELL COVER

Dimentions : 4 x 4 inch square
Length : 5 feet

NOTES:

Location: Right Abutment
Upstream Side Of Crest

Surface Elev: 4745.43 feet

DH4A TOP Elev: 4747.81 feet

DH4B TOP Elev: 4747.88 feet

Top of Cover Elev:

Northing:

Easting:

Surveyed By: Bob Arrington and Craig Stiles

Date Surveyed: 10/2003

DESCRIPTION

0 to 5 SAND

5 to 18 BENTONITE

18 to 28 SAND

21 to 26 SCREEN FOR DH4B

28 to 48 BENTONITE

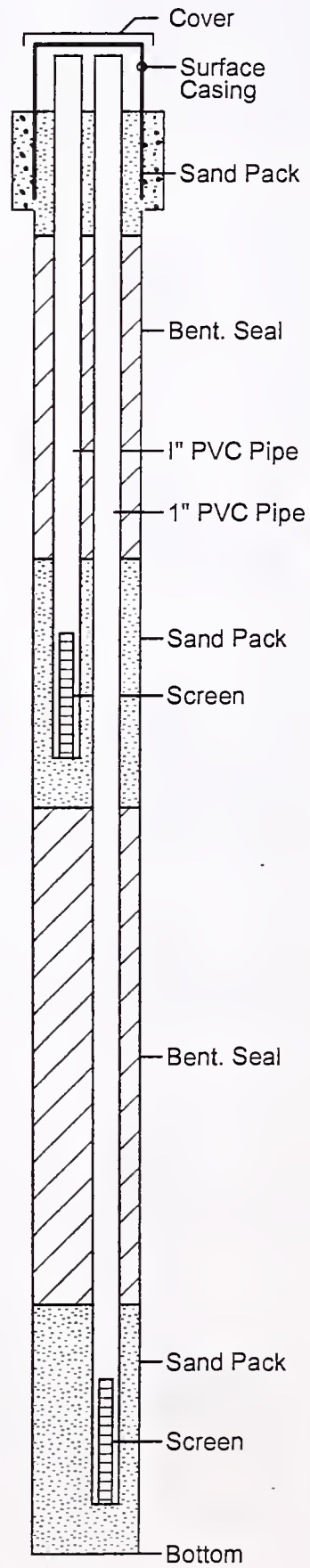
48 to 58 SAND

51 to 56 SCREEN FOR DH4A

58 BOTTOM OF HOLE
(Bedrock Contact)

Depth In Feet

Well1: DH-4A
Well2: DH-4B



08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-4 WC.bor

SOIL LOG OF BOREHOLE NO: DH5

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/7/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	4745	X	0 to 2' ROAD BASE gravelly sand, brown, subangular gravel fragments, 4 to 6" cobbles, dry to slightly moist	GP								
		X	2 to 13' SANDY CLAY, brown, slightly moist to moist (moisture increasing with depth), meduium stiff, low plasticity	CL		SS	3 4 5	14	16/18	89%		
5	4740											
		X				SL	3 4 12	14	15/18	83%	1.8	9 to 10.5' Torvane = 4.8 tsf
10	4735											12' Hit gravel, went through but back into it at 14'
		X	13 to 27' GRAVELLY SAND, dark brown to brown, slightly moist to moist (moisture increasing with depth), gravel fragments up to 1.5", interspersed layers of sandy silt	GM		SS	3 25 30	56	3/18	17%		
15	4730											
		X				SL	6 18 20	31	15/18	83%		20 to 20.5' % Finer #200 = 9.1%
20	4725											
		X				SS	50+	0	1/18	6%		24 to 25.5' Sampler spoon likely hitting a rock to cause refusal
25												

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 ...ATER_PRI\PROJECTS\Bob AlWell Logs\WillowWillow DH-5 Soil.bor

SOIL LOG OF BOREHOLE NO: DH5

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/7/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Brian Grant

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 4745.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
25	4720	☒		GM		SS	50+	0	1/18	6%		
			27 to 46' SANDY CLAY, brown, slightly moist to moist (moisture increasing with depth), medium stiff, low plasticity									
30	4715	☒				SL	0 4 6	7	16/18	89%		29 to 30.5' Sample - very moist, some gravel pieces % Finer #200 = 57% LL=26% PL=15% PI=11%
35	4710	☒		CL		SS	1 5 5	8	15/18	83%		
40	4705	☒				SL	2 4 6	6	16/18	89%	0.65	39 to 40.5' Torvane = 1.7 tsf % Finer #200 = 56% m = 25.5% Dry Unit Weight = 100.8 pcf Nondispersive
45	4700	☒				SS	1 1 3	3	18/18	100%		46' Refusal of 50 blows for 1". Assume bedrock interface.
50		☒	46' BOTTOM OF HOLE			SS	50+	0	1/18	6%		

Hollow Stem Auger 4 1/2" ID
Hammer 140 lbs 30" drop hydraulic
Standard Spoon OD = 2.0" ID = 1.5"
Brass Liner Spoon OD = 2.5" ID = 2.0"

08-29-2005 G:\WATER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-5 Soil.bor

WELL COMPLETION LOG NO: DH5

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Willow Creek	DRILL RIG	: CME 750
DATE STARTED	: 10/7/2003	DRILLING METHOD	: Auger
DATE COMPLETED	: 10/7/2003	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: SK Geotechnical	LOGGED BY	: Bob Arrington
DRILLER	: Bill Neff	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 4745.6 | Well Construction Information | DESCRIPTION | Depth In Feet

0 — 4745

WELL CONSTRUCTION

Date Compl. : 10/7/2003
Hole Diameter : 8 inch
DNRC Rep. : Craig Stiles

5 — 4740

STANDPIPE

Material : PVC pipe
Diameter : 1 inch
Joints : screwed
Bottom Cap : screwed

10 — 4735

WELL SCREEN

Material : PVC pipe
Diameter : 1 inch
Length : 5 feet
Opening : .02 inch

15 — 4730

SAND PACK

Material : Colorado Silica 10/20

ANNULUS

Material : 3/8 inch Bentonite

20 — 4725

WELL COVER

Dimentions : 4 x 4 inch square
Length : 5 feet

25 — 4720

NOTES:

Location: Right Abutment
Downstream Side Of Crest

30 — 4715

Surface Elev: 4745.62 feet

DH5A TOP Elev: 4747.94 feet

DH5B TOP Elev: 4747.99 feet

35 — 4710

Top of Cover Elev:

Northing:

40 — 4705

Easting:

Surveyed By: Bob Arrington and Craig Stiles

Date Surveyed: 10/2003

45 — 4700

50

0 to 5 SAND

5 to 19 BENTONITE

19 to 27 SAND

21 to 26 SCREEN FOR DH5B

27 to 37 BENTONITE

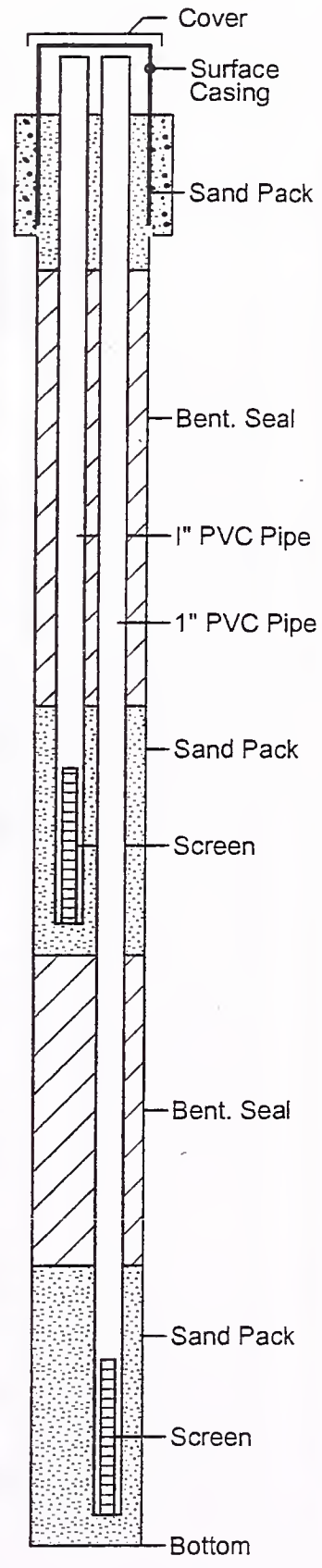
37 to 46 SAND

40 to 45 SCREEN FOR DH5A

46 BOTTOM OF HOLE
(Bedrock Contact)

0 5 10 15 20 25 30 35 40 45 50

Well1: DH-5A
Well2: DH-5B



08-29-200: ...TER_PR\PROJECTS\Bob A\Well Logs\Willow\Willow DH-5 WC.bor

APPENDIX E

PROJECT DRAWINGS

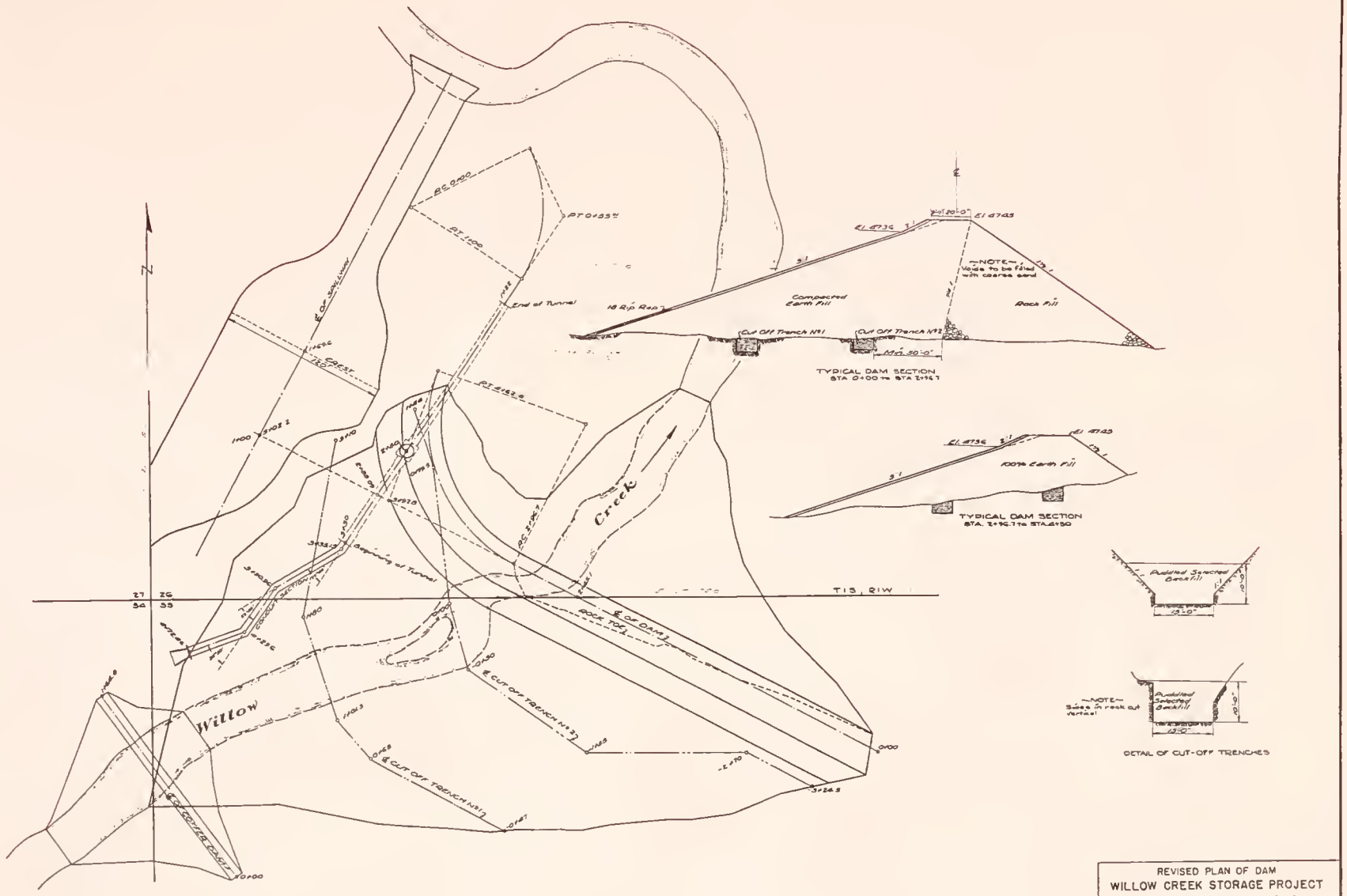
(NOTE: These reduced project drawings are design drawings and not "As Builts". These drawing should be used for reference only. The SWPB has the full size project drawings.)

ELEVATION CORRECTION

BOR Bench Mark – new datum	4748.82 feet elevation
Spillway Crest – old datum (as identified in O&M)	4736.00 feet Elevation
Difference	12.82 feet
Actual Measurement (BM to Spillway Crest)	9.64 feet
Correction	3.18 feet

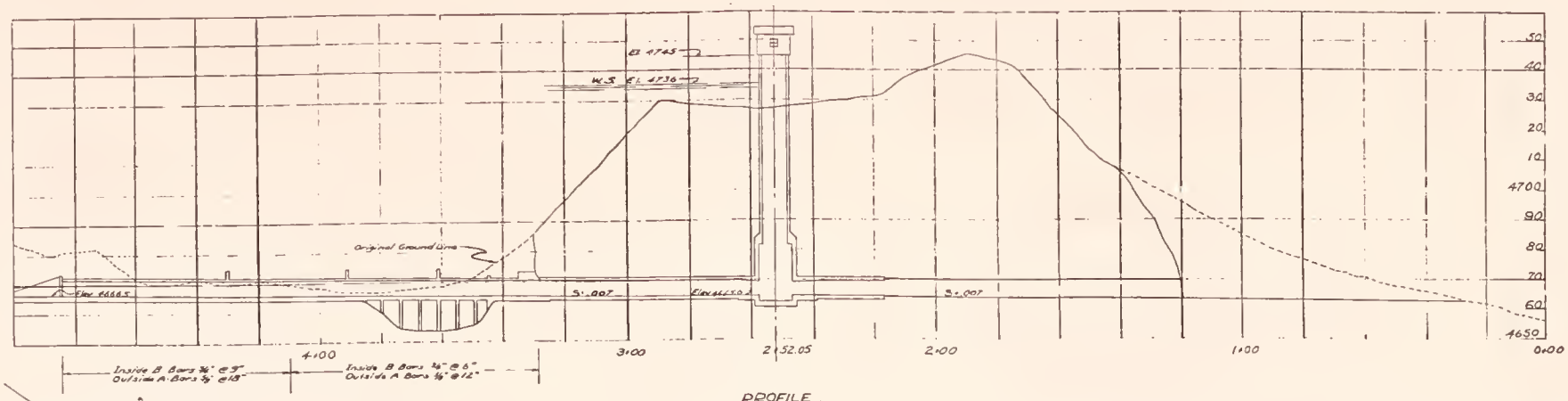
To Go From:
Old datum to new datum – add 3.18'
New datum to old datum – subtract 3.18'

E2 2005

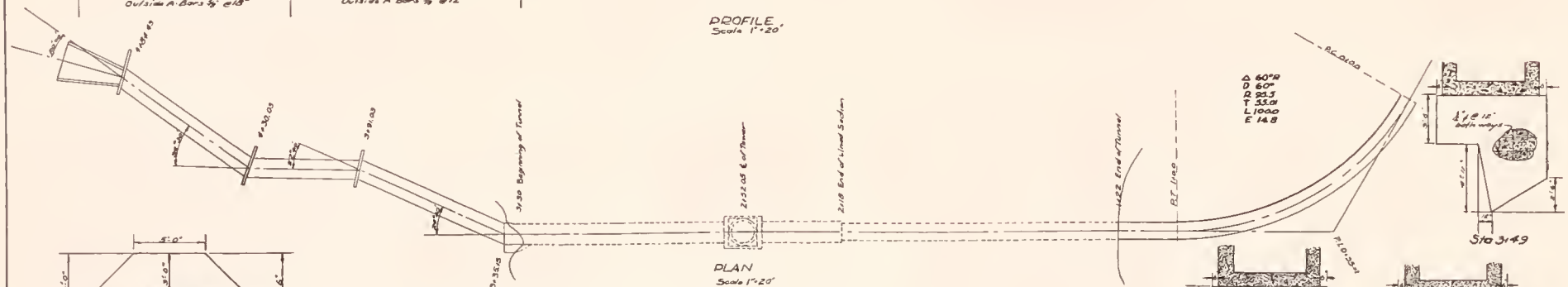


REVISED PLAN OF DAM
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA AUGUST 1936
SCALE 1" = 30'

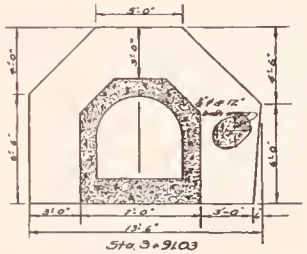
CHANGE ORDER NO. 3



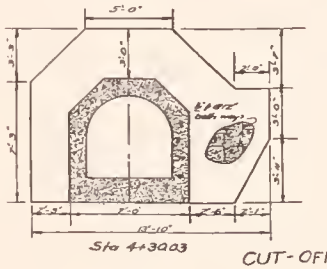
PROFILE
Scale 1"=20'



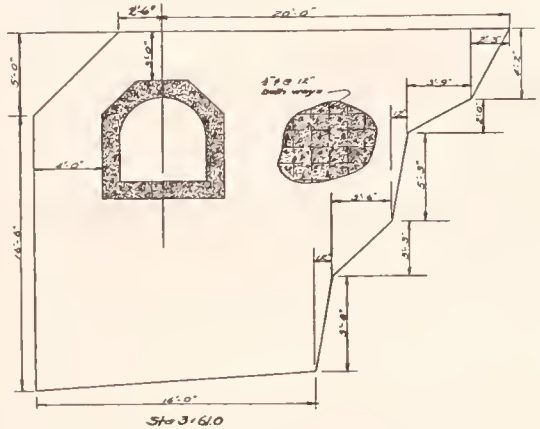
PLAN
Scale 1"=20'



Sta 3+91.03

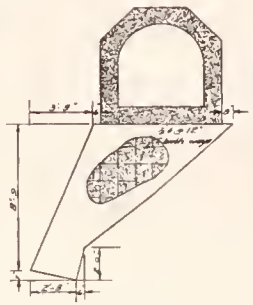


Sta 4+30.03

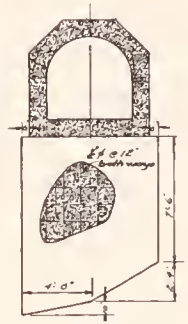


Sta 3+61.0

CUT-OFF WALLS
Scale ½"=1'-0"

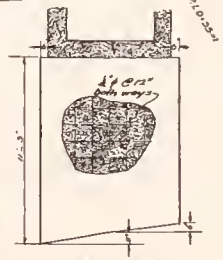


Sta 3+7[illegible]

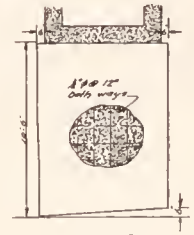


Sta 3+35

PIERS
Scale ¼"=1'



Sta 3+67.5



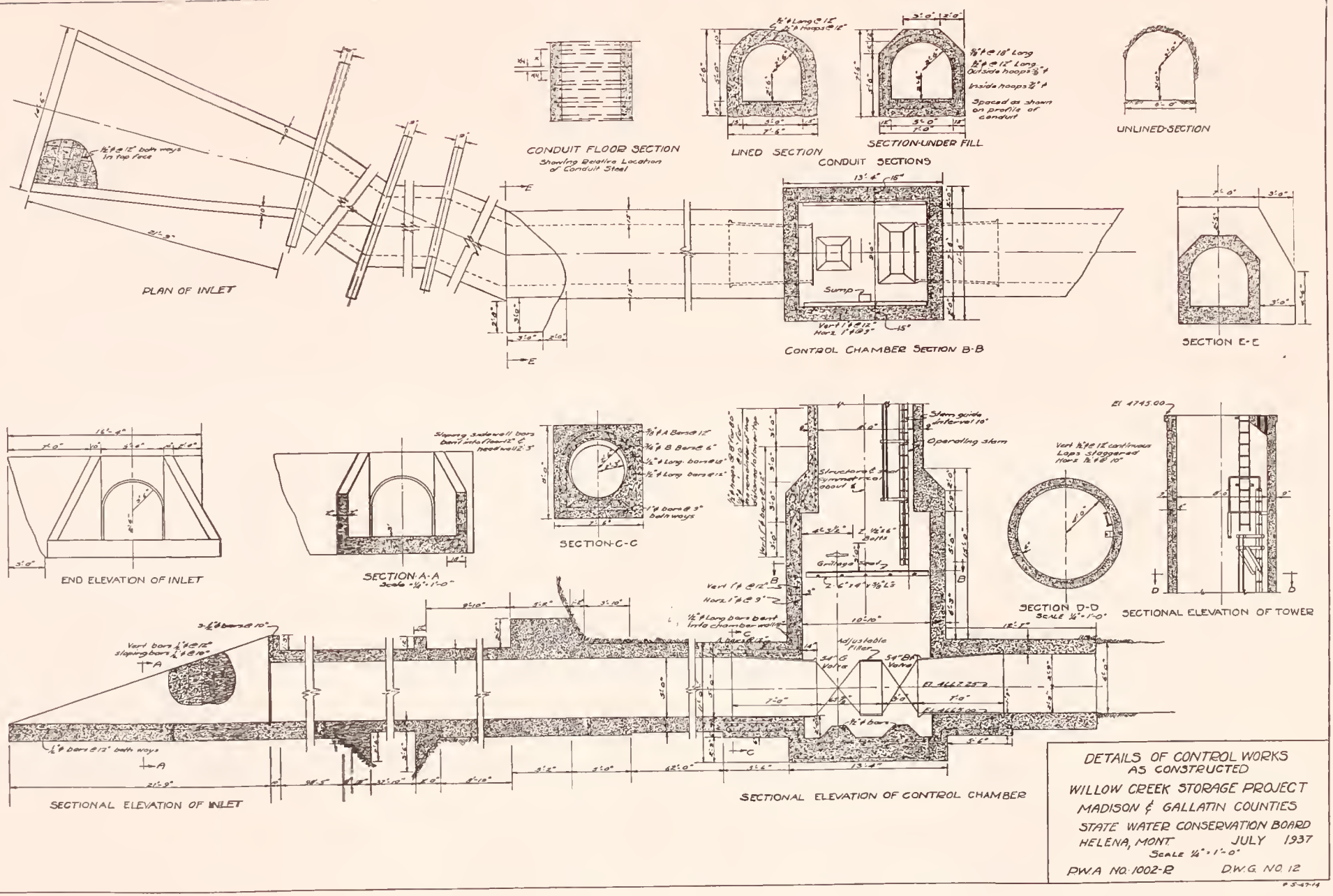
Sta 3+35

PLAN & PROFILE OF CONTROL WORKS
DETAILS OF CUT-OFFS AND PIERS
AS CONSTRUCTED

WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONT JUNE 1937
SCALE AS SHOWN
PWA NO. 1002-R DRAWING NO 11

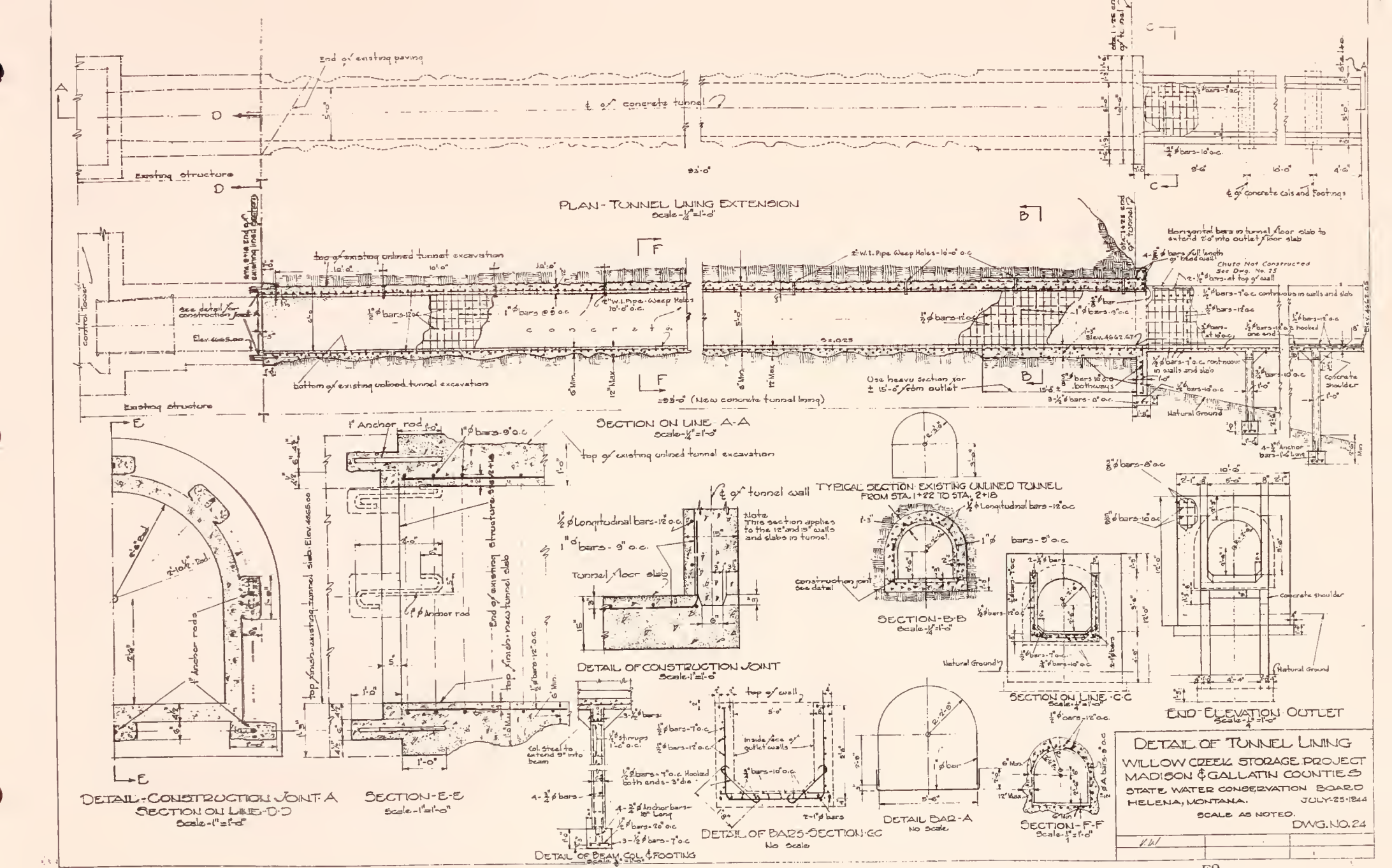
Drawn by	EGF	Traced by	JJ		

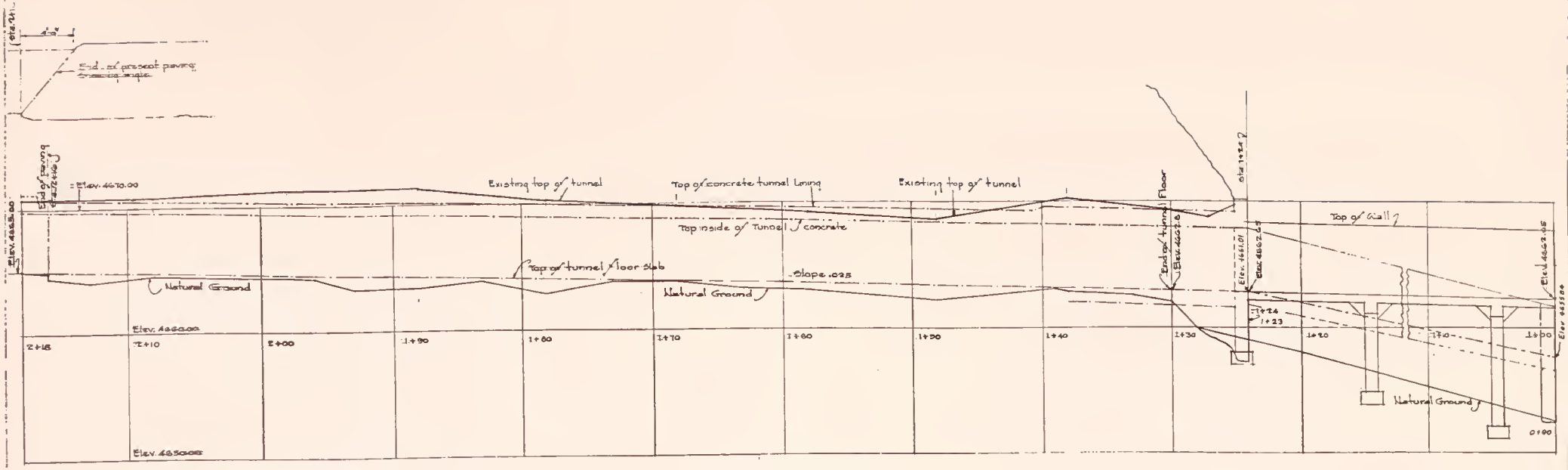
45-47-3



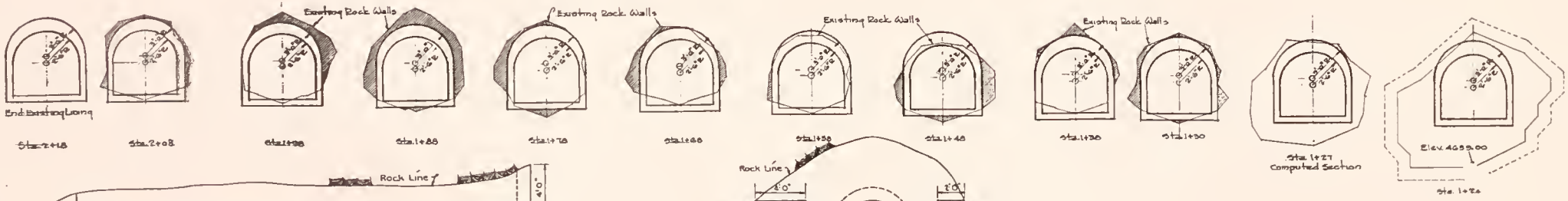
DETAILS OF CONTROL WORKS
AS CONSTRUCTED
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONT JULY 1937
SCALE ¼" = 1'-0"
P.W.A. NO. 1002-B D.W.G. NO. 12

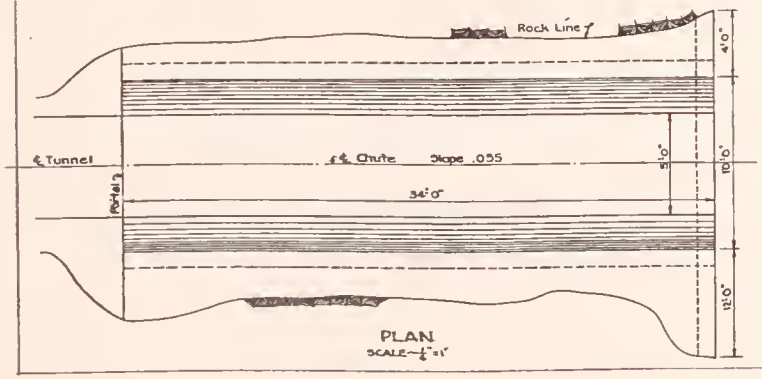
P-S-47-14


PLAN - TUNNEL LINING EXTENSION
Scale - 1/4" = 1'-0"
End of existing paving
℄ of concrete tunnel
Existing structure
℄ of concrete cols and footings
SECTION ON LINE A-A
Scale - 1/4" = 1'-0"
top of existing unlined tunnel excavation
bottom of existing unlined tunnel excavation
Use heavy section for ± 15'-0" from outlet
Natural Ground
Concrete shoulder
Chute Not Constructed See Dwg. No. 25
TYPICAL SECTION EXISTING UNLINED TUNNEL FROM STA. 1+22 TO STA. 2+18
DETAIL OF CONSTRUCTION JOINT
Scale - 1" = 1'-0"
Note This section applies to the 12" and 15" walls and slabs in tunnel.
Tunnel floor slab
SECTION - B-B
Scale - 1/4" = 1'-0"
SECTION ON LINE - C-C
Scale - 1/4" = 1'-0"
END ELEVATION OUTLET
Scale - 1/4" = 1'-0"
DETAIL - CONSTRUCTION JOINT - A
SECTION ON LINE - D-D
Scale - 1" = 1'-0"
SECTION - E-E
Scale - 1" = 1'-0"
DETAIL OF BEAM, COL. & FOOTING
DETAIL OF BARS - SECTION - G-G
No Scale
DETAIL BAR - A
No Scale
SECTION - F-F
Scale - 1/1" = 1'-0"
DETAIL OF TUNNEL LINING
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA.
JULY-25-1944
SCALE AS NOTED.
DWG. NO. 24

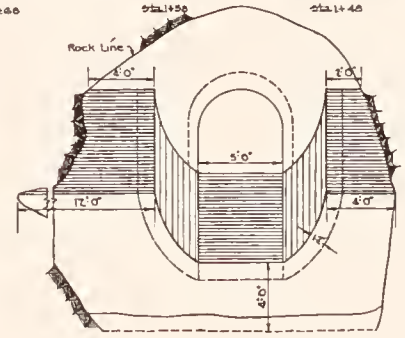


PROFILE OF TUNNEL
Scale-$\frac{1}{4}$"=1'0" Horizontal & Vertical





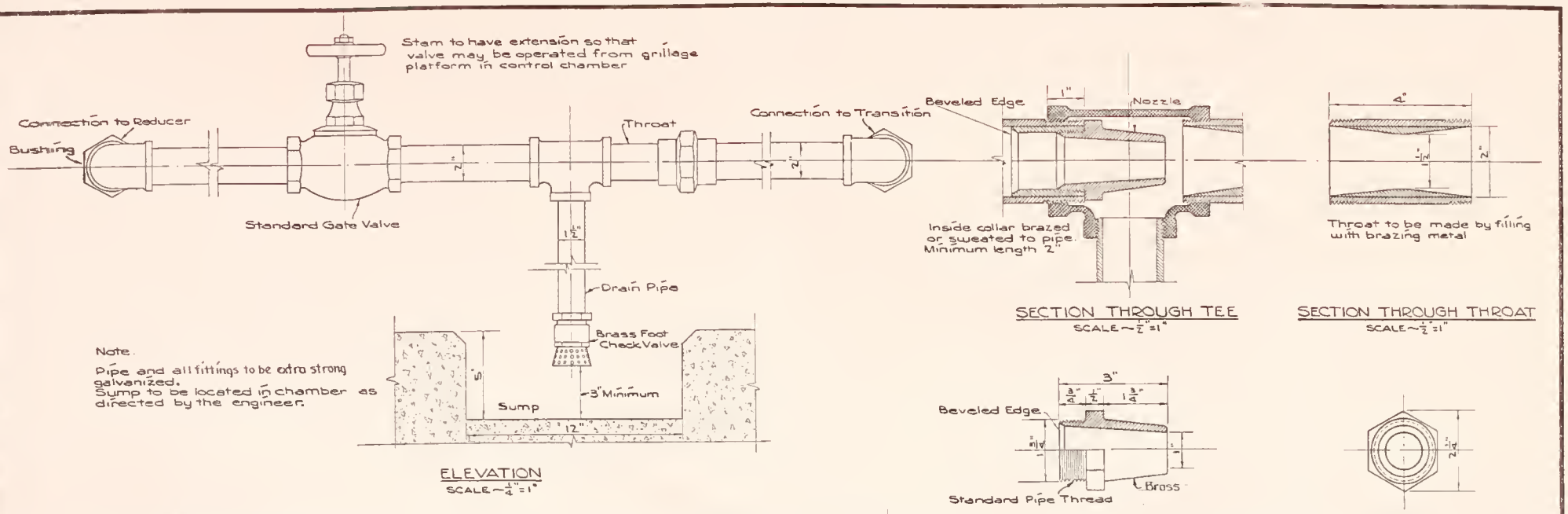
PLAN
SCALE-$\frac{1}{4}$"=1'



END ELEVATION
SCALE-$\frac{1}{4}$"=1'

PROFILE AND CROSS SECTIONS
OF TUNNEL LINING.
WILLOW CREEK STORAGE PROJECT
MADISON & GALLATIN COUNTIES
STATE WATER CONSERVATION BOARD.
HELENA, MONTANA.
JUNE-18-1945
SCALE AS NOTED
DWG. No. 25

KW



Note.

Pipe and all fittings to be extra strong galvanized.
Sump to be located in chamber as directed by the engineer.

ELEVATION
SCALE ~ $\frac{1}{4}$" = 1"

SECTION THROUGH TEE
SCALE ~ $\frac{1}{2}$" = 1"

SECTION THROUGH THROAT
SCALE ~ $\frac{1}{2}$" = 1"

NOZZLE DETAIL
SCALE ~ $\frac{1}{2}$" = 1"

PLAN
SCALE ~ $\frac{1}{4}$" = 1"

STANDARD JET PUMP

FOR SUMP DRAINAGE

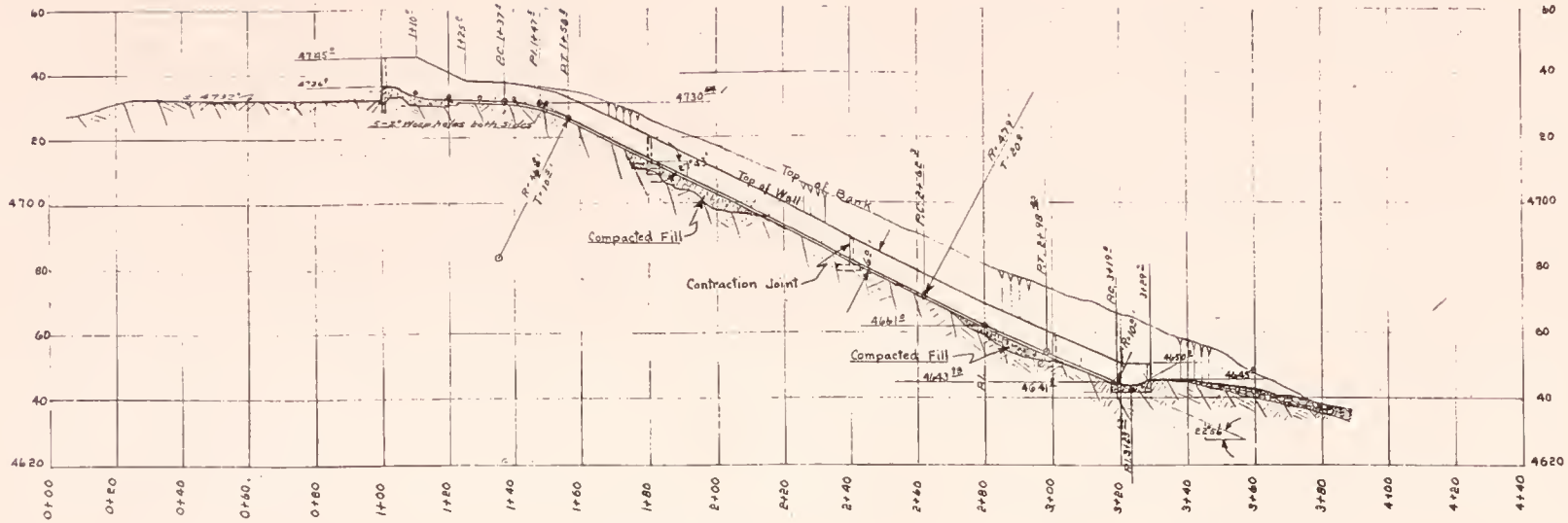
STATE WATER CONSERVATION BOARD

HELENA, MONTANA OCT. 31. 1935

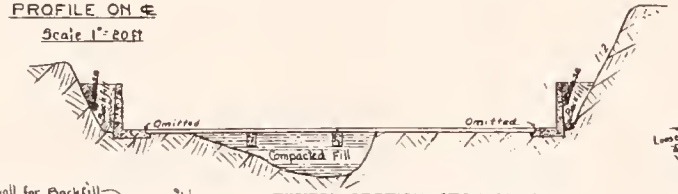
SCALE AS SHOWN

DWG S-10

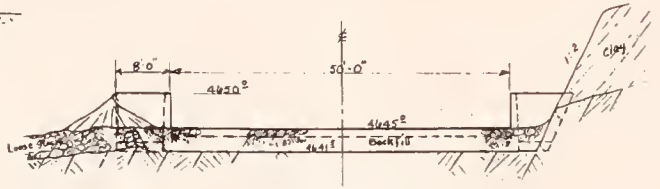
Drawn by	W.V.J.	Checked by	G.F.S		
Traced 3/8" by	J.C.K.				



PROFILE ON ℄
Scale 1"=20ft

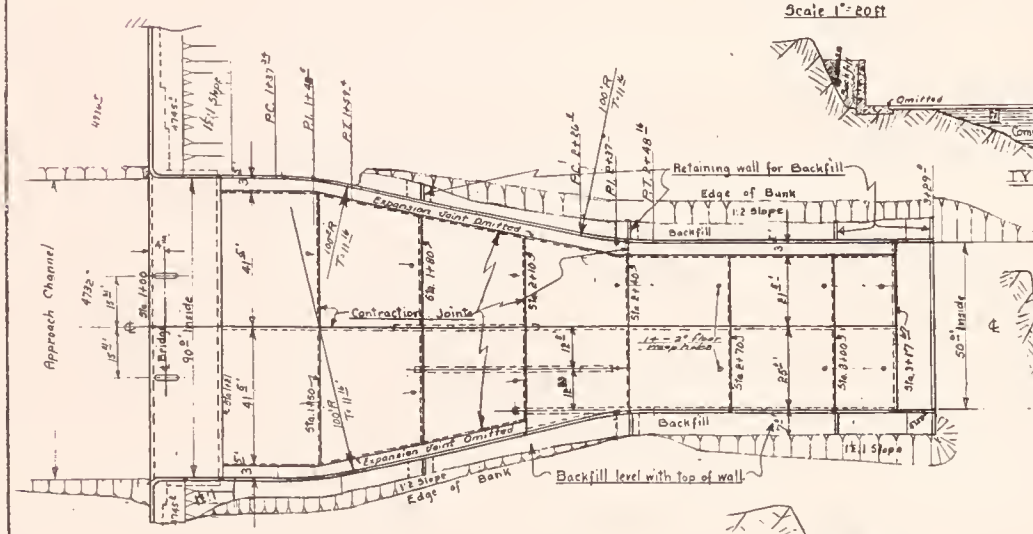


TYPICAL SECTION STA. 1+80 to 2+10
Scale 1"=10ft.

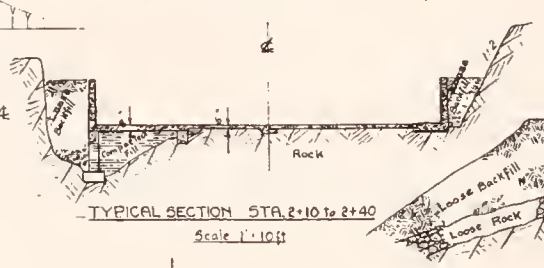


LOWER END ELEVATION
Scale 1"=10 ft.

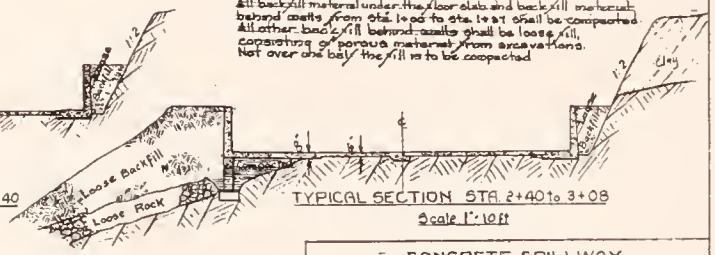
Note:
All backfill material under the floor slab and backfill material behind walls from Sta. 1+00 to Sta. 1+21 shall be compacted. All other backfill behind walls shall be loose fill, consisting of porous material from excavations. Not over one half the fill is to be compacted



PLAN
Scale 1"=20ft.



TYPICAL SECTION STA. 2+10 to 2+40
Scale 1"=10ft



TYPICAL SECTION STA. 2+40 to 3+08
Scale 1"=10ft

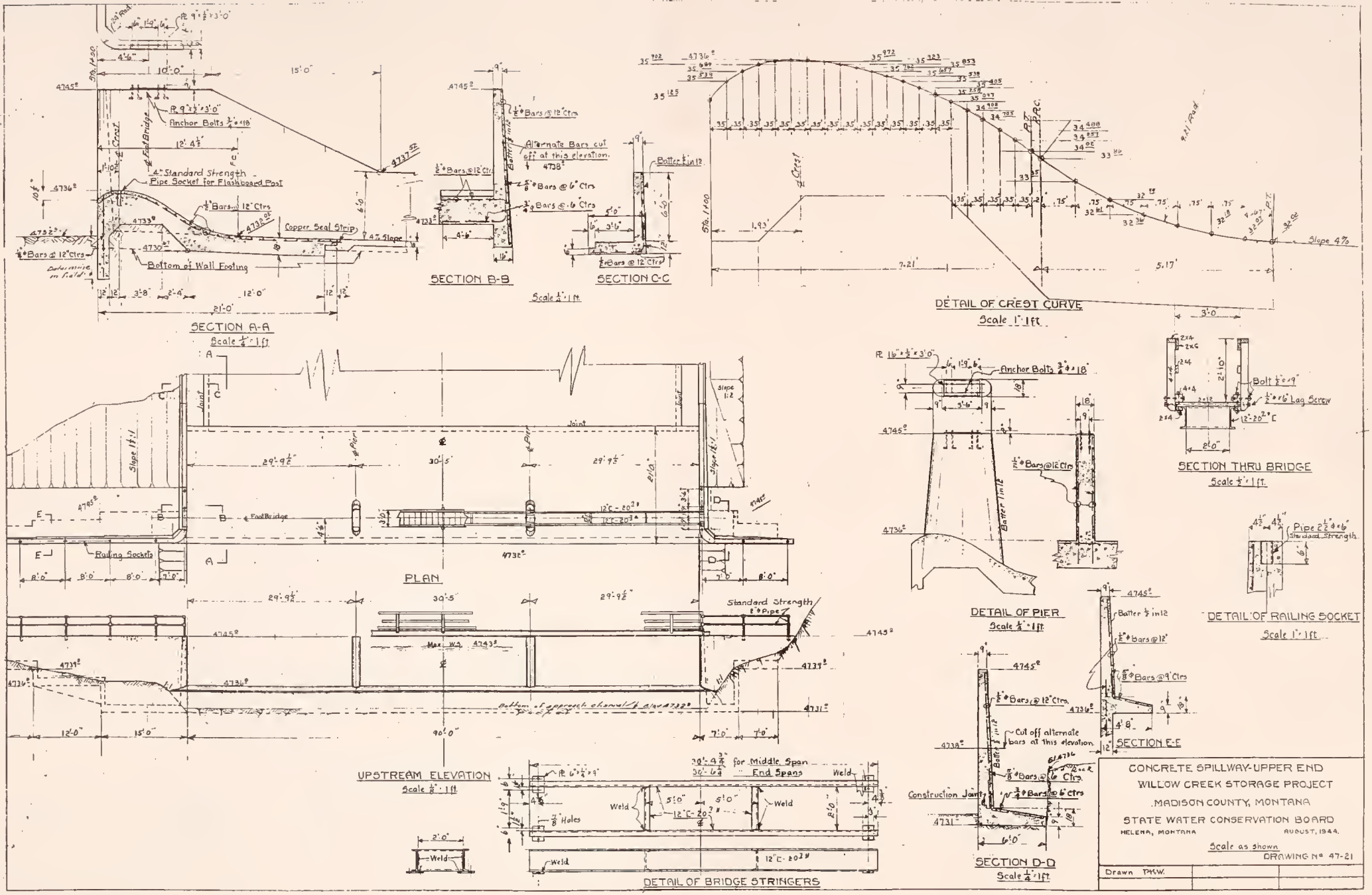
TYPICAL SECTION STA 1+21 to 1+80 Scale 1"=10ft

All sections looking South

CONCRETE SPILLWAY
PLAN, PROFILE, & SECTIONS
WILLOW CREEK STORAGE PROJECT
MADISON COUNTY, MONTANA.
STATE WATER CONSERVATION BOARD
HELENA, MONTANA. OCT. 1944

Scale as shown.
DRAWING No 47-20

Drawn	T.H.W.		


SECTION A-A
Scale ¼" = 1 ft.
SECTION B-B
SECTION C-C
Scale ½" = 1 ft.
DETAIL OF CREST CURVE
Scale 1" = 1 ft.
PLAN
UPSTREAM ELEVATION
Scale ⅛" = 1 ft.
DETAIL OF BRIDGE STRINGERS
DETAIL OF PIER
Scale ½" = 1 ft.
SECTION THRU BRIDGE
Scale ½" = 1 ft.
DETAIL OF RAILING SOCKET
Scale 1" = 1 ft.
SECTION D-D
Scale ½" = 1 ft.
SECTION E-E
CONCRETE SPILLWAY-UPPER END
WILLOW CREEK STORAGE PROJECT
MADISON COUNTY, MONTANA
STATE WATER CONSERVATION BOARD
HELENA, MONTANA
AUGUST, 1944.
Scale as shown
DRAWING No 47-21
Drawn PKW.